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digest

Industrial platform floors:

mezzanine and raised storage

Digest 437

This Digest has been prepared in response to difficulties being experienced with the design and Building Regulation control of mezzanine raised storage platform floors.

It aims to ease such difficulties by providing specific authoritative guidance on these specialised structures which are not especially addressed in current Codes of practice.

It gives guidance on imposed loading and chipboard decking; these are the two principal issues that cause the most commonly experienced difficulties.

Designing, manufacturing and installing mezzanine and raised storage platform floors requires specialised knowledge in order to achieve satisfactory and safe performance. This Digest gives authoritative technical guidance on their design, construction and use, and provides an acceptable approach for meeting Building Regulation compliance, particularly with respect to Part A *Structure*. It does not give extensive, detailed advice on fire safety.

This Digest is for specifiers, designers, manufacturers, Building Regulation enforcement authorities and others responsible for the management and safe use of these cost effective and adaptable structures. It is not a 'stand alone' document: its implementation requires reference to other authoritative documents, such as Building Regulation Approved Documents and British Standards.

This Digest introduces a loading classification concept which, subject to the adoption of an appropriate management scheme (described later), may be substituted for the current imposed loading requirements recommended in BS 6399: Part 1. In the absence of such a Management scheme, the loading requirements given in BS 6399: Part 1 should be strictly adhered to.

Figure 1 A typical platform floor

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General information and scope of guidance

The term 'industrial buildings' includes all those facilities traditionally referred to as 'workshops', 'factories' and 'warehouses' built in industrial, business and retail parks. During the last twenty years or so the use of such industrial buildings in the UK has undergone fundamental change in response to such factors as the growth of consumerism, the impact of information technology and the development of storage and handling systems. As a consequence, the complete 'volume' of these buildings is commonly utilised these days, not merely the exploitation of their 'floor area'. Moreover, these buildings are often required to be readily amenable to the numerous adaptations brought about by changes in tenancy and/or business practices.

Industrial buildings are typically large warehouse structures with smaller, single or two-storey office accommodation either joined to, or situated within, the warehouse. The ground floors are commonly required to support heavy static loads as well as dynamic loads from handling equipment and fork lift trucks etc. As most industrial buildings have at least a six-metre headroom to eaves, there is usually ample scope to introduce further working levels for shelving, racking, pallet trucks and platform floors. Such equipment typically installed in industrial buildings is provided by a specialist and competitive industry.

Platform floors are commonly referred to as 'mezzanine floors' or 'raised storage platforms'. Although the second term clearly relates to the specific use of 'storage', these floors are commonly used for a variety of applications such as light workrooms and offices.

In common with other products available on the market, platform floors need to satisfy legal requirements relating to product liability and 'fitness for purpose'. In addition, there is usually an obligation on the supplier to ensure that the facility is compliant with the Building Regulations and that its designer complies with the Construction, Design and Management (CDM) Regulations. While the Building Regulations stipulate general functional requirements for these installations, little authoritative technical guidance is available to assist the designer on the alternative means of meeting compliance. This digest provides a rational approach to meeting Building Regulation compliance, particularly with respect to Part A *Structure*, and to enable the industry and users to gain maximum benefit from these economical and adaptable structures.

This Digest assumes the following:

- The design of the platform floor is entrusted to a chartered structural or civil engineer or other appropriately qualified person, and that the execution of the work is carried out under the direction of appropriately qualified supervisors.
- The platform floor is of lightweight steel construction (hot or cold rolled components) with a chipboard floor decking. Although other materials, such as plywood and steel plating, can also be used for decking, the guidance provided in *Chipboard floor decking* on page 7 relates only to that material.
- The platform floor is supported on an adequate concrete ground floor slab or foundation.
- The platform floor is not connected to any other part of the building for support or restraint unless the ability of the building to safely provide such support has been verified.
- The platform floor is not supported by a racking (ie shelving) structure which would require special consideration.
- The platform floor is not used for private sports, disco or similar leisure purposes.
- With chipboard decking, the platform floor is located in an environment approximating to Service Class 1 or 2 of BS 5268: Part 2. The guidance does not apply to chipboard decking to platform floors located in a Service Class 3 environment, eg washrooms, canteens or cold/refrigeration rooms.
- The chipboard used for decking is Type P5 or P7 to EN 312-5 and EN 312-7 respectively.
- The use of the platform floor is monitored under a Management Scheme similar to that proposed in this Digest.
- All the statutory requirements mentioned in this Digest are complied with.

The load classification concept with its attendant management scheme should assist in overcoming two difficulties commonly experienced with the design and use of these structures:

- the cost penalty of adopting the loading requirements given in BS 6399: Part 1 for such structures where intended for much lighter use;
- monitoring the safe use of such structures at times of changed usage (excluding a statutory 'material change of use') which typically results from a change of ownership.

Two principal issues cause the most commonly experienced difficulties: *imposed loading* and *chipboard decking*.

Imposed loading The guidance provides alternative loading requirements commensurate with the intended use of the installation, subject to certain operational conditions and arrangements being accepted by users and controllers. Adopting such an approach should provide a practical procedure for ensuring the economical procurement and safe use of these popular structures in a range of industrial applications.

Chipboard decking The guidance provides an interim design method made necessary by factors that have tended to militate against the safe use of this material. These include the non-availability of type C5 chipboard (the only grade currently recommended by BS 5268: Part 2 for structural use), the BSI 'declaration of obsolescence' in 1997 with regard to BS 5669: Part 5 (now replaced by BS 7916), and the fact that the available CEN Product Standards do not at present provide characteristic properties of chipboard to facilitate the use of Eurocode 5, DD ENV 1995-1-1: 1994.

Statutory requirements

The relevant statutory requirements applicable to the UK are as follows:

The Building Regulations 1991 (applicable in England and Wales)
the functional requirements are given in Schedule 1 with regard to Part A - Structure, Part B - Fire Safety etc.
Detailed guidance approved by the Secretary of State for meeting the Building Regulations is given in the following relevant Approved Documents:

- Approved Document A Structure;
- Approved Document B Fire Safety;
- Approved Document K Stairs, ramps and guards;
- Approved Document M Means of access for the disabled.

Other approaches may provide compliance.

The Building (Scotland) Regulations 1990 with subsequent amendments

- Regulation 9 Compliance with building standards. Technical Standards Part A;
- Regulation 10 Fitness of materials. Technical Standards Part B;
- Regulation 11 Structure. Technical Standards Part C;
- Regulation 12 Structural fire precautions. Technical Standards Part D;
- Regulation 13 Means of escape from fire and facilities for fire fighting. Technical Standards Part E;
- Regulation 32 Stairs, ramps and protective barriers. Technical Standards Part S.
- Regulation 33 Access and facilities for disabled people. Standards Part T.

The Building Regulations (Northern Ireland) 1994

- Part D Structure;
- Part E Fire safety;
- Part EE Means of escape in case of fire;
- Part H Stairs, ramps and guarding;
- Part R Access and facilities for disabled people.

Table 1 Minimum characteristic imposed loads

Office	Uniformly distributed	2.5 kN/m^2
Workroom (without storage)	Proprietary lightweight partition	0.5 kN/m^2
Canteens (but not kitchens)	Concentrated load	2.7 kN
Light storage	Uniformly distributed	3.5 kN/m^2
	Shelving	2.5 kN/bay
	Concentrated load	3.5 kN
Medium storage	Uniformly distributed	5.0 kN/m^2
	Shelving	4.0 kN/bay
	Hand pallet truck	7.0 kN
	Concentrated load	5.0 kN
Heavy storage	Uniformly distributed	7.0 kN/m^2
	Shelving	5.0 kN/bay
	Powered pallet trucks	12.0 kN
	Concentrated load	6.0 kN

Note:
The application of the concentrated load shall be in accordance with cl. 5.1.3 of BS6399: Part 1.
The assumed area of the concentrated load shall be recorded in the *Management Document.*

Imposed loading

BS 6399: Part 1 gives dead loads and minimum recommended characteristic imposed loads for floors of offices, retail, industrial and warehouses etc. The Code provides uniformly distributed loads per metre height of storage as well as recommended concentrated loads assumed over the actual area of application in positions that produced the maximum stress and deflection for strength and serviceability criteria respectively.

For 'general storage' purposes other than those specifically identified (cold storage, stationery etc), the Code recommends a uniformly distributed imposed loading of 2.4 kN/m^2 per metre of available storage height and a concentrated load of 7.0 kN for most of the occupancy classes that commonly relate to platform floors. However, the application of these loads for platform floors should be considered with regard to the intended use of the platform floor, the type of storage materials and type of handling conditions etc.

In some cases it may be concluded that the BS 6399: Part 1 recommended loading for 'general storage' is not appropriate for a particular installation and that a more realistic characteristic loading, commensurate with the intended use, is given in the load classification system shown in Table 1. Exceptionally, a loading higher than that given in the Code may be warranted for particularly heavy industrial use.

In the past, building control enforcement authorities have been reluctant to accept platform floors designed for carrying imposed loading other than that recommended in BS 6399: Part 1. This is because there is no provision under the current Building Regulations to allow them to monitor the use of such structures (continuing control). Without such powers, enforcement authorities have no means of ensuring that the structures were being safely used and loaded as intended by the designer and would therefore be reluctant to accept an imposed loading value less than that recommended in the Code of practice. However, with the introduction of the Management Scheme (discussed on page 12), Building Control enforcement authorities will now have the opportunity to accept the more flexible imposed loading recommendations provided in Table 1 in the knowledge that the owner and/or user of the installation have a duty to effect the monitoring procedure stipulated under the Scheme.

The structure

There are essentially two generic forms of floor structure: *inset* and *oversailing* – see Figure 2. *Oversailing* floors give a deeper floor construction than inset floors because the deck is supported by secondary beams bearing on top of the primary beams.
Inset floors have their secondary beams cleated into the web of the primary beams; this results in an overall reduction in floor depth.

The structure of platform floors typically comprises steel columns with baseplates, primary and secondary beams, floor decking, bracing members, stairs, and edge protection. The framing may be of hot-rolled or cold-formed steel, or combinations of both. While the concept of large spans with a minimum number of columns may be preferred by the building user for operational reasons, the implications of the resulting deeper beams and larger baseplates on the users' operations at ground floor level need to be fully assessed.

Ground floor concrete slabs within industrial buildings are normally used for heavy-duty operations; platform floors are more suited to lighter, less demanding uses. Locating small parts storage, light workrooms and small offices on the raised level of a platform floor usually results in a more efficient use of floor area. Careful attention must be paid to the means of escape, location of stairs etc to achieve a safe, useful and cost-effective design.

The structural decking spanning between the supporting secondary beams may be subjected to uniformly distributed loads and an array of concentrated loads (static and mobile) as well as concentrated line loads for partitions of offices etc. It is often subject to high levels of wear and tear from the traffic such as pallet trucks. The selection of suitable decking material is, therefore, highly dependent on the intended use of the platform floor; it may need an abrasion resistant, anti-slip surface.

The decking is also commonly used as an effective diaphragm to give lateral support to the secondary beams.

The designer should be aware of the tendency for lightweight mezzanine floor structures to vibrate in use and that, depending on the intended use of the facility, specialist advice on such serviceability criterion may need to be sought.

Other materials

The guidance in this Digest is restricted to chipboard as the decking material because this is currently the most common material in use in the UK. However, other materials, such as plywood and steel plating, may be more suitable for the intended use and life-span of the platform floor.

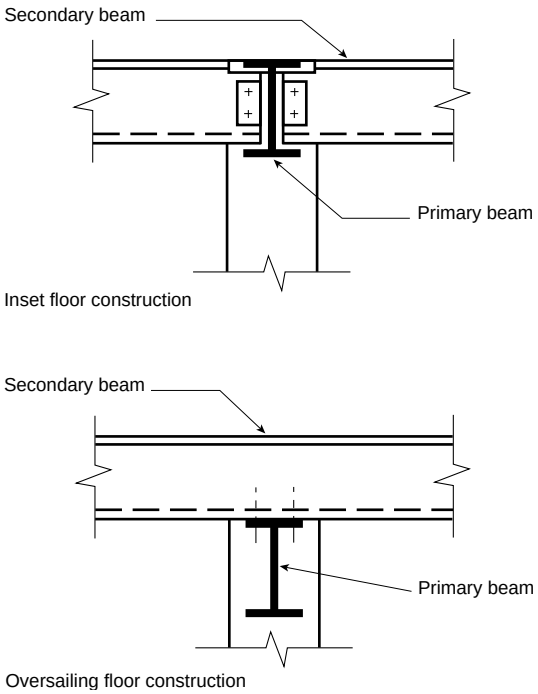


Figure 2 Inset and oversailing floor construction

Stability

Lateral stability of platform floors requires special attention at the design stage as these structures are commonly freestanding on simple baseplates. Platform floors should not be connected to the main structure of the building for lateral support unless a design check has been carried out to determine whether the building can afford such support.

To safeguard stability and to avoid excessive movement and vibration under normal use (which may include the use of pallet trucks), platform floors need to be robust and stiff. Lateral stability checks should be carried out based on a notional horizontal force of 2 % of the sum of the dead and the vertical imposed load assumed to act at decking level. This magnitude of notional horizontal force is recommended in view of the relatively low ratio of dead/imposed loading condition which applies to such structures and the fact that they are not usually designed to sustain wind loading.

For a structure designed in accordance with BS 5950: Part 1, the notional horizontal force shall be increased by the relevant partial load factors given in Table 2.2 of that Code.

The effectiveness of the decking acting as a horizontal diaphragm for transmitting lateral forces to vertical bracing elements depends on the form and frequency of the decking fixings to the supporting secondary beams. Unless the adequacy of such composite action with the decking can be demonstrated, plan bracing must be provided. Stability bracing or the provision of portal sway frames shall be

provided, although in the case of sway frames, account should be taken of any serviceability limitations.

Partitions built beneath the decking should not be used as shear walls unless they are integral with the framing members of the platform floor and if reasonable provision is made to safeguard against their unauthorised removal (eg by including appropriate warnings in the *Management Document* – see page 12).

Designers should also consider the likelihood of accidental impact loads from activities at ground floor level (eg by forklift vehicles). Where possible, the use of vehicles at the ground floor level shall be segregated away from the mezzanine floor. Any columns considered to be at risk from impact shall be protected with appropriately designed bollards or similar protective measures.

Columns

Columns of platform floors are usually of hot-rolled steel sections but, exceptionally, may be of cold-formed sections. Their design should allow for possible pattern loading and account should be taken of the moments generated by the eccentricities at the beam/column connections. Their effective lengths should be based on the values given in Table 2, depending on whether the columns are considered as being braced (eg by diagonal bracing) or unbraced (ie when designed as a sway frame), together with consideration of the degree of end fixity – see Figure 3.

When adopting the values in Table 2, particular regard should be given to the practicality of specifying fixed bases to columns in terms of the baseplate design and moment capacity of the baseslab. Similarly, any presumption of fixity at the head of the column should take full account of the actual detailing of the beam to column connections, especially when cap-plates are provided.

The effective column lengths given in Table 2 are valid where the column head is restrained by beams that actually frame into the sides of the column. In the case of oversailing floors, the secondary beams are less effective, especially if they are additionally offset from the line of the column.

Primary beams

Primary beams for platform floors are usually hot-rolled UB sections; some manufacturers use 'I' beams fabricated from two cold-formed channel sections back to back.

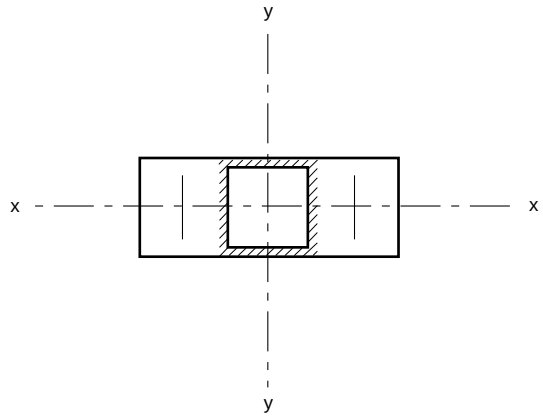
The assumed effective lengths of primary beams used in designing the platform floor should be derived considering the following – see Clauses 4.3.3 and 4.3.5 of BS 5950: Part 1:

- For inset floors, where the depth of the inset secondary beams is equal to, or greater than, half the depth of the primary beams, the integrity of the composite construction of the decking and secondary beams will normally provide adequate lateral and torsional restraint to the primary beam, provided a minimum two bolt cleated connection is incorporated. Where the depth of secondary beams is less than half the depth of the primary beam, torsional restraint should not be assumed, even though lateral restraint may be assumed to be adequate.
- In oversailing floors, the torsional restraint afforded to the primary beam is likely to be negligible and should be disregarded, even though the lateral restraint afforded to the beam will normally be adequate.

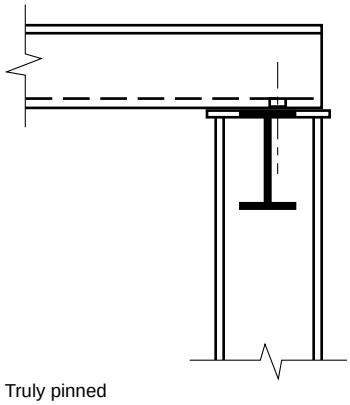
Table 2 Effective length factors for various directional restraint conditions at head and base of column

Type of column	Base	Head			
		Effectively restrained	Partially restrained	Nominally pinned	Truly pinned
Braced	Effectively restrained	0.70 L	0.80 L	0.85 L	0.90 L
	Partially restrained	0.80 L	0.85 L	0.90 L	0.95 L
	Nominally pinned	0.85 L	0.90 L	0.95 L	1.00 L
	Truly pinned	0.90 L	0.95 L	1.00 L	AVOID
Unbraced	Effectively restrained	1.50 L	2.00L	2.50L	3.00L
	Partially restrained	2.00 L	2.50 L	3.00 L	4.00 L*
	Nominally pinned	2.50 L	3.00 L	AVOID	AVOID
	Truly pinned	3.00 L	AVOID	AVOID	AVOID
Unbraced where at least five columns act together in resisting sway *and storage loads are not being supported*	Effectively restrained	1.20 L	1.50 L	2.00 L	2.50 L
	Partially restrained	1.50 L	2.00 L	2.50 L	3.00 L*
	Nominally pinned	2.00 L	2.50 L	AVOID	AVOID
	Truly pinned	2.50 L	AVOID	AVOID	AVOID

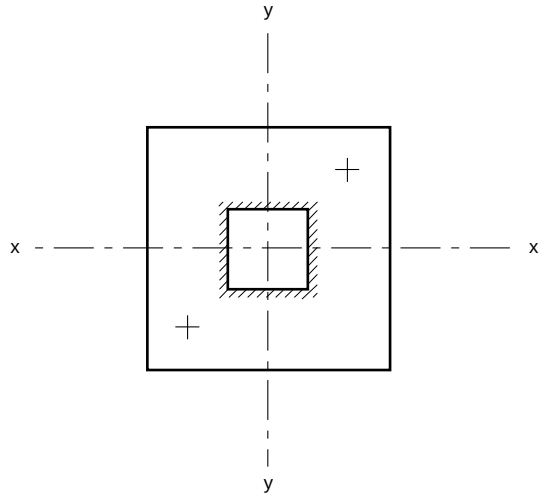
* For buckling about major axis only. To be avoided for buckling about minor axis



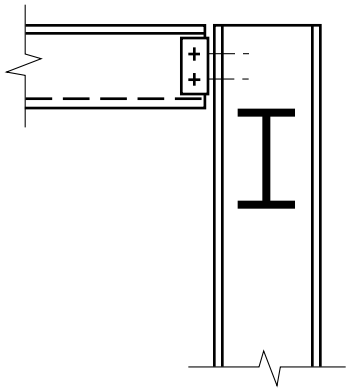
Nominally pinned x - x Partially restrained y - y



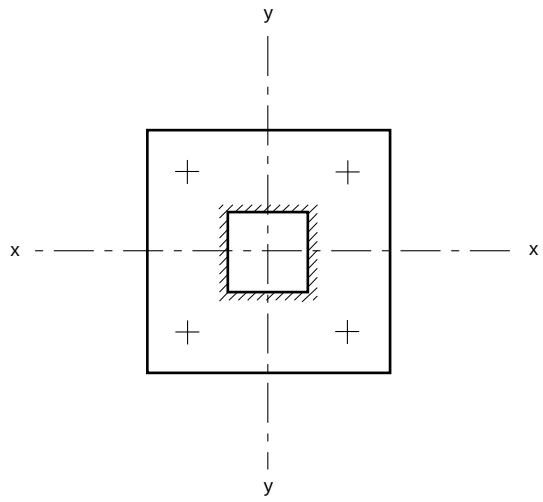
Truly pinned



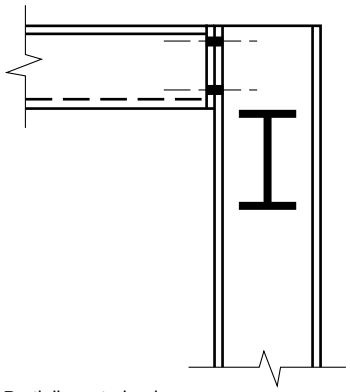
Nominally pinned x - x Nominally pinned y - y



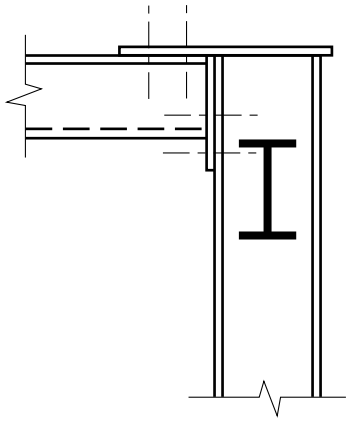
Nominally pinned



Effectively restrained x - x Effectively restrained y - y



Partially restrained



Effectively restrained

Column base details **Column head details**

Figure 3 Examples of column end restraint conditions

Secondary beams

Deck support beams are commonly cold-formed steel sections, either simple channel section or of a more complex shape. Manufacturers of these sections can provide literature concerning the mechanical properties of their products and safe load tables, but the designer of the floor is advised to check that the assumptions and support conditions given in the manufacturer's literature will be achieved in practice. The following common features should also be considered.

- The light-gauge secondary beams must be restrained laterally to achieve their maximum flexural capacity. This may be achieved by ensuring that the beams are adequately fixed to the decking at suitable centres with screw fixings, the design of which may be based on manufacturer's tests. Furthermore, under sustained loading these asymmetric sections tend to twist resulting in a reduction of their strength and stiffness, although some proprietary sections perform better than others in this regard. The design of channel section secondary beams should always allow for the effects of torsion. One solution is to install tie bars between facing pairs of beams, provided the bars are taut.
- The beams should be designed for strength and serviceability under all loading conditions.
- The designer of the floor should aim to provide a structure designed to serviceability criterion that is commensurate with the intended use of the facility.
- In the case of inset floors, the secondary beams are usually bolted to the main beams by folded steel plate cleats. With thin-gauge materials it is important to ensure that the folded cleat safely carries the loads. Such information on load capacity may be determined from manufacturers' tests or from an appropriate analysis. In the use of thin-gauge sections the capacity of many bolted connections is limited by the bearing stress.
- In the case of oversailing floors, there are two additional factors that require consideration: web bracing and web restraint. It is not uncommon in lightly loaded floors for the secondary beams to be simply connected to the primary beams with bolts passing through the adjoining flanges. At such locations it is important to check for web crushing and the local stability of members and to provide web stiffeners where necessary.

Chipboard floor decking

In common with many other wood-based panel products, the structural performance of chipboard depends on both the ambient environment in which the material is placed and the period of time that the material sustains its imposed loading. Chipboard should not be used for a Service Class 3 environment according to BS5268: Part 2. In practice, the ambient environment of the majority of industrial buildings where platform floors are installed corresponds to Service Class 1 or 2 which are defined as follows:

Service Class 1 is characterised by a moisture content in the materials corresponding to a temperature of 20°C and relative humidity of the surrounding air exceeding 65% for only a few weeks per year. In such moisture conditions chipboard will attain an average moisture content not exceeding 8%.

Service Class 2 is characterised by a moisture content in the materials corresponding to a temperature of 20°C and relative humidity of the surrounding air exceeding 85% for only a few weeks per year. In such moisture conditions chipboard will attain an average moisture content not exceeding 12%.

Concentrated loads from racking systems and concentrated line loads such as load-bearing partitions should not be supported directly by the chipboard decking, unless proven by design or by prototype testing.

BS5268: Part 2 does not provide guidance on the design of chipboard other than for type C5 which is not generally available. To overcome this deficiency, the following simplified interim guidance is based on the principle rules given in DD ENV 1995-1-1:1994.

To minimise movement of the decking in service, the chipboard panels should not be subjected to prolonged environmental conditions, either prior to or during installation, that lie outside the limits stipulated for Service Class 2 of BS5268: Part 2. To avoid excessive dimensional movement, it is essential that chipboard is conditioned for the environment (to reach its equilibrium moisture content) in which it is to be used.

If the platform floor, or part of it, is regularly used by lifting equipment traffic, a protective wearing surface may be needed. Protection, such as chequer plates for heavy duty activities, may be particularly appropriate at pallet gate positions.

Table 3 Load-duration classification for chipboard decking

Load-duration Classification	Estimated accumulated duration of characteristic load	Examples of typical loading relevant to platform floors
Permanent	more than 10 years	Self-weight, archival storage
Long-term	6 months – 10 years	Storage, heavy shelving, office filing
Medium-term	1 week – 6 months	Offices, shelving, pallet trucks
Short-term	less than one week	Wind, imposed concentrated loads for maintenance
Instantaneous	Instantaneous	Accidental load such as vehicle impact and explosions

Load-duration classifications

The imposed loading recommendations given in Table 1 relate to various load duration periods which should be considered when determining strength and stiffness of timber or wood-based panel products, such as chipboard. Where the loads in any given combination have different durations, the design of the floor should be based on the shortest duration of any load component included in that combination. Designers should therefore consider all variable and permanent loads, and their corresponding durations, in order to derive the most critical load combination and its duration. For the purpose of determining the duration of loads on chipboard decking the load-duration classification given in Table 3 should be used.

Design

Numerous grades of chipboard are available (eg P4, P5, P6 and P7) to suit a variety of uses. Chipboard used for platform floors should be type P5 to BS EN 312-5 or P7 to BS EN 312-7.

The mechanical test properties of the chipboard should not be used directly in design without appropriate modification factors. As interim guidance, the modification factors given in Table 4 for types P5 and P7 may be used in the limit state design approach given in DD ENV 1995-1-1:1994 by multiplying the mechanical test strength properties based on current EN standards (5 percentile values), obtained from the chipboard manufacturer, by $k_{strength}$ provided that the moisture content of the chipboard is not expected to exceed 8% and 12% for Service Classes 1 and 2 respectively during use in service.

Deflections should be calculated (according to normal engineering principles) using characteristic moduli given in the BS or manufacturers' literature. The calculated deflection should be multiplied by the appropriate modification factor ($k_{deflection}$) given in Table 4 to account for long term creep of chipboard, provided that the moisture content of chipboard is not expected to exceed the foregoing 8% and 12% limits during its use in service. The permissible deflection can be

Table 4 Design values of strength and deflection using modification factors

Load-duration class	Modification factors for strength and deflection							
	For Type P5 chipboard				For Type P7 chipboard			
	Service Class 1 (SC1)		Service Class 2 (SC2)		Service Class 1 (SC1)		Service Class 2 (SC2)	
	$k_{strength}$	$k_{deflection}$	$k_{strength}$	$k_{deflection}$	$k_{strength}$	$k_{deflection}$	$k_{strength}$	$k_{deflection}$
Permanent	0.23	3.25	0.15	4	0.31	2.5	0.23	3.25
Long term	0.35	2.5	0.23	3	0.39	2.00	0.31	2.5
Medium term	0.5	1.75	0.35	2	0.54	1.50	0.42	1.75
Short term	0.65	1.00	0.46	1.4	0.69	1.00	0.54	1.3

Design values of strength and deflections:

(a) For strength: $f_d \leq k_{strength} \cdot f_k$ should be used in calculations for a given Service Class

(b) For deflection: $\gamma_d = k_{deflection} \cdot \gamma$ should be less than or equal to:

$\gamma_d \leq$ 0.005x span (span up to 610 mm) for permanent and long-term loadings

$\gamma_d \leq$ 0.010x span (span up to 610 mm) for medium- and short-term loadings

$\gamma_d \leq$ 0.003x span (span more than 610 mm) for all load-durations;

where:

f_d = design strength using 'Design loads' in Table 5

f_k = characteristic strength (5 percentile) based on current EN standards, obtained from the manufacturer

$k_{strength}$ = modification factor for strength properties

γ_d = design deflection

γ = calculated deflection using 'Design loads' in Table 5

$k_{deflection}$ = modification factor for deflection

assumed to be 0.005 x span for permanent and long-term load-durations and 0.01 x span for medium and short-term load-durations for spans up to 610 mm. A more restricted deflection limit of 0.003 x span is required for spans of more than 610 mm.

Designers also have the choice of designing chipboard decking on the basis of prototype/performance testing. This approach is an acceptable alternative to design calculations for demonstrating structural adequacy, especially where:

- the decking configuration and its means of support may not be amenable to calculations, or where calculations are deemed inappropriate;
- the quality of the materials used for decking and its fixings is disputed.

Prototype/performance testing should be based on BS EN 1195 and modified in accordance with prEN 12871 and DD ENV1995-1-1.

'Design loads' Appropriate 'Design loads' for chipboard decking should be derived for the strength and deflection calculations. At least two major types of loads should be considered in design: Permanent (G_k) and Variable (Q_k). Permanent loads are continuously sustained during the life of the structure. Variable loads are imposed loads that are sustained for variable periods but not continuously during the life of the structure. The design value of a combination of loads is calculated from Table 5.

Table 5 Determining design loads for chipboard

Design load (for strength) = Largest of $1.35\ [\Sigma G_{k,} + \Sigma Q_k]$ OR $[1.35\ \Sigma G_{k,} + 1.5\ Q_{k,1}]$

where:

$Q_{k,1}$ = the dominant variable load

ΣG_k = the sum of permanent loads

$\Sigma_i Q_k$ = the sum of all variable loads

Design load (for deflection) = $\Sigma G_{k,j} + Q_{k,1} + 0.6\ \Sigma_{i>1} Q_{k,i}$

where:

$\Sigma G_{k,j}$ = the sum of permanent loads

$Q_{k,1}$ = the dominant variable load

$\Sigma Q_{k,i}$ = the sum of other variable loads

Punching shear load

The punching shear capacity of chipboard needs careful consideration in the design of platform floors, especially where chipboard is used to support high concentrated loads from pallet truck wheels or shelving/racking legs, etc. Chipboard's resistance against punching shear load failure is more critical than plywood's as it tends to exhibit a brittle mode of failure at ultimate conditions under test. In view of this, designers should ensure that chipboard is designed to sustain the floor loading with an adequate factor of safety. The design punching shear capacity of types P5 and P7 chipboard for different thicknesses, contact areas and load-durations, can be calculated from Table 6. They must be equal to or greater than 'Design loads'.

Fixings and joints

The frequency of chipboard fixings affects both strength and stability of the decking. There is very little published information available on screwed joints between chipboard and steel supporting members. Performance tests on fasteners and panels may therefore be required to determine the resistance of screwed joints to lateral and axial loads. Such test results may be available from the fixing manufacturers.

Table 6 Punching shear design loads for different thicknesses and contact areas

Load-duration class	Design punching shear load for P5 chipboard only N		Design punching shear load for P7 chipboard only N	
	SC1	SC2	SC1	SC2
Permanent	$5.8\ t\ d^{0.667}$	$3.8\ t\ d^{0.667}$	$10.9\ t\ d^{0.667}$	$8.1\ t\ d^{0.667}$
Long term	$8.8\ t\ d^{0.667}$	$5.8\ t\ d^{0.667}$	$13.7\ t\ d^{0.667}$	$10.9\ t\ d^{0.667}$
Medium term	$12.5\ t\ d^{0.667}$	$8.8\ t\ d^{0.667}$	$18.9\ t\ d^{0.667}$	$14.7\ t\ d^{0.667}$
short term	$16.3\ t\ d^{0.667}$	$11.5\ t\ d^{0.667}$	$24.2\ t\ d^{0.667}$	$18.9\ t\ d^{0.667}$

where:

t = thickness of chipboard in mm

d = diameter of the loaded area or side of a square or the smallest dimension of a rectangle in mm

The performance of the joints is a major factor in determining the load-carrying capacity of chipboard, particularly where concentrated loads require support.Using tongue and grooved (T & G) jointed chipboard can be more economical than square-edged boards which need additional support at joints.

For platform floors, T & G boards are usually laid with their longer edges aligned across the secondary beams and with their shorter edges continuously supported by the secondary beams. The boards shall be laid with the lines of the shorter edges of adjacent boards staggered. Continuous support under the longitudinal T & G joints is not required.

The recommended design punching shear capacities given in Table 6 are dependent on the T & G joints being glued. If unglued T & G jointed boards are used, the punching shear values need to be derived from tests in accordance with BS EN 1195.

The main benefits of glued T & G joints are:

- breakage of loose tongues under concentrated loads (static and mobile) is avoided;
- they help transfer load from adjacent boards;
- enhanced bending and shear strengths are mobilised at the joint position;

Stairs

To provide adequate safety for people using platform floors, stairs should conform to the guidance given in Approved Documents B, K and M, particularly where the stairs provide a means of escape in case of fire. The provision of companion-way ladders, defined in BS 5395: Part 3 is not recommended where regular access is required or where light loads will be carried.

The stairs should be designed to sustain the minimum characteristic imposed loads given in Table 7.

The stairs should not be used for moving heavy objects onto the platform floor. Special lifting equipment should be provided for this purpose. Warning notices shall be displayed adjacent to the stairs accordingly.

Table 7 Minimum imposed loads on stairs

Type of activity or occupancy of platform floor	Uniformly distributed load kN/m^2	Concentrated load kN
Office, workroom or storage	3.0	2.0

Guarding

Guarding should be provided at the edges of platform floors and associated stairs to protect people or equipment operating on the floor from falling. Additional guarding may be necessary to prevent objects falling from the platform and injuring people below. Approved Document K gives guidance on guarding height requirements and refers to BS 6399: Part 1 for recommendations on imposed horizontal loadings. Additional guidance on the design of infill panels is given in BS 6180 and BS 5395: Part 3 also provides more general guidance on protective barriers.

These Standards will be superseded by a European Standard in due course. For factories and warehouses, Approved Document K recommends that the edges of floors are protected with guarding a minimum of 1100 mm high. For stairs and ramps, the minimum height of guarding is 900 mm.

Approved Document K also recommends that stairs and ramps are provided with a handrail (to aid balance) at a height of between 900 mm and 1000mm. This does not usually present a problem in practice as handrails are the most common means of meeting the Building Regulations guarding requirements for platform floors.

To comply with BS 6399: Part 1, the guarding should be designed to safely sustain a minimum characteristic imposed horizontal line loading of 0.74 kN/m run of guarding assumed to be acting at a height of 1100 mm above the finished level of the platform floor. For stairs, the height is the pitch line drawn through the nosings: this recommendation is preferred to that given in Table 4 of BS 5395: Part 3.

In some instances, it may be necessary to protect people below the platform floor from danger of falling objects by providing toe plates (kicking plates) and steel mesh infill (or similar material) to the guarding.

If toe plates are provided they should be robust and imperforate, and should extend to at least 100 mm above the finished platform surface. The design of the guarding should preferably provide for anchorage fixings to be connected to the supporting steel structure. Reliance should not be assumed on the integrity of the decking for support unless verified by design calculations or testing.

Foundations and baseplates for platform floors

Concrete ground floor slabs in industrial buildings are usually used for heavy-duty operations, unlike lightweight platform floors which are more suited to less onerous purposes. Such ground floors may have been originally specified for a particular uniformly distributed loading, but the actual imposed loads are commonly an array of concentrated or local patch loads from racking, trucks, partitions, lightweight platform floors etc.

The slab will be either suspended or bear directly on the ground. If suspended, a structural assessment will be needed of the slab and supporting members to verify that the loading from the mezzanine floor will be carried safely.

The ability of ground-bearing slabs to support the mezzanine floor can be assessed on the basis of the following publications:

- *Design of floors on ground*
  Cement and Concrete Association; TR550; June 1982.
- *The design of ground-supported concrete industrial floor slabs*
  British Cement Association Interim Technical Note (ITN) 11; April 1988.
- *Concrete industrial ground floors - a guide to their design and construction*
  Concrete Society Technical Report No 34; 2nd Edition 1994.

Baseplates of platform floors may be seated directly on the ground floor slab if its surface is reasonably flat, in good condition and has adequate strength. However, for baseplates greater than 250 mm square and where 'partially or effectively restrained' base conditions have been assumed, the baseplates should be grouted.

Baseplates should be fixed to the slab with a minimum of two drill fixings per baseplate. These are for positioning only and should not be relied upon for any other functions unless verified by design.

Baseplates should be designed and proportioned so that the resulting spread of load does not overstress the concrete ground slab, the sub-base or the ground. To determine the required size of the baseplates, it is necessary to ascertain the slab thickness, the condition and grade of concrete, the extent of any reinforcement, together with the nature of the sub-base and underlying ground. Local authority records may provide some information on these questions or it may be necessary to undertake a simple core investigation and ground assessment by a competent specialist company.

Fire

The provision of more than one working level in a building demands detailed consideration of means of escape from the raised areas and the fire resistance necessary of the elevated structure. Consideration should be given to:

- methods of fire protection and surface spread of flame;
- smoke ventilation and detection systems;
- number of people on the floor;
- type of usage of floor;
- means of escape, travel distance, number of escape routes;
- connections (if any) to existing structure.

Approved Document B gives detailed guidance on ways of meeting the regulatory fire safety requirements and includes certain dispensations in fire resistance which may be applied where a raised floor is used for storage purpose only with limited access. Where platform floors are put to several different uses, careful consideration of the needs of the users and the advice of the Building Regulation enforcement authorities are essential to develop a scheme suitable to all parties.

It is possible to provide fire resistance to the structure with proprietary suspended ceiling systems etc, but this is often an unsatisfactory option where such lightweight materials can be damaged easily by the relatively heavy-duty activity on the ground floor. Furthermore these lightweight ceilings are only effective if the tiles are fully clipped and particular attention is paid to penetration by lighting fixtures, services etc.

Management scheme

Platform floors and their associated partitions, shelving etc, can have a significant impact on business operations; in order to exploit them efficiently it is imperative that their safe operating limitations are fully appreciated by owners, users and regulation enforcement authorities. Adoption of the recommendations for platform floors given in *Imposed loading* on page 3 shall be conditional to a Management Scheme being established for each facility.

The Scheme shall be operated voluntarily by the building owner or user, and shall be the dedicated responsibility of a named, competent manager.

The scheme is not intended to impose a responsibility on the local enforcement authority for continuity of Building Regulation control. The Scheme shall comprise the following:

- the provision of a *Management Document*;
- the provision of displayed *Loading Notices*;
- the appointment of competent persons (other than the Scheme manager) to undertake periodic inspections, surveys and structural appraisals.

Management Document

The *Management Document* shall be prepared and submitted with the application documents for Building Regulation approval. It should contain all relevant information pertaining to the approved use of the floor, including any provisions agreed in respect of the appropriate regulations and Loading Notices. An example of the contents of such a Management Document is given opposite. Copies of the *Management Document* shall be retained by the owner and user to facilitate monitoring of the facility. If there is a change of ownership or user, the retiring owner or user shall send a copy of the *Management Document* to the new owner or user.

Loading Notices

To facilitate the safe use of a platform floor, it is important to display permanently on the structure a *Loading Notice* detailing the load category and the limitations of use for which the structure was designed.

The Loading Notice:

- should be legible and securely attached to the platform floor at strategic points on the structure, eg adjacent to access stairs and at any dedicated loading points;
- should not be removed unless the required use of the structure has warranted modification (subject to Building Regulation control) or, if working operations necessitate, the transfer of a *Loading Notice* to a more prominent location on the structure;
- should include at least the information shown in the example below;
- should specify the reference number of the *Management Document*.

Loading Notice

THIS NOTICE MUST NOT BE REMOVED

THIS PLATFORM FLOOR IS TO BE USED ONLY FOR:

.....

.....

Allowable imposed load values:

Uniformly distributed (kN/m^2) .....

Concentrated (kN) ..... over a minimum contact area of ..... (mm^2)

Shelving (kN/bay) .....

Hand or powered pallet truck (kN) .....

Requirements for any additional spreaders under concentrated loads

.....

.....

SUPPLIER'S NAME AND ADDRESS .....

MANAGEMENT DOCUMENT REFERENCE No.....

Management Document Reference No .....

1 Address of premises
.....
2 Name and address of owner/landlord ..... tel no .....
3 Tenant (if different from above) ..... tel no .....
4 Name and address of manufacturer ..... tel no .....
5 Name and address of
applicant for Building Regulation consent..... tel no .....
6 Name of competent Scheme Manager ..... tel no .....
7 Name and address of
Building Regulation Enforcement Authority ..... tel no .....
8 Name and address of Fire Authority ..... tel no .....
9 Name and address of Health & Safety Authority ..... tel no .....
10 Name and address of
Planning Supervisor (under CDM regulations)..... tel no .....
11 Date of Building Regulation application ..... tel no .....
12 Reference No of Building Regulation Application ..... tel no .....
13 Type of activity/occupancy on platform floor .....
14 Maximum allowable imposed loading:
Uniformly distributed load .....
Concentrated load .....
15 Allowable types of equipment and pallet trucks to be used on the floor .....
16 Reference nos of design calculations and 'as built' construction drawings .....
17 Location of design calculations and 'as built' construction drawings .....
18 Additional agreed conditions of use
.....
19 Inspection Arrangements:
Name of competent person authorised to undertake regular inspections
.....
Name of competent person authorised to undertake annual condition surveys
.....
Name of competent person authorised to undertake structural appraisals
.....
20 Key items to be verified by regular inspections
.....
21 Purpose of annual condition surveys
.....
22 Purpose of structural appraisals
.....

Monitoring by competent persons

To maintain the safe use of the platform floor, the owner or user of the installation should arrange for regular inspections, annual condition surveys and structural appraisals to be undertaken by competent persons with the appropriate experience. For the annual condition surveys and the structural appraisals, such persons shall be chartered structural or civil engineers, or other appropriately qualified persons. Agreement on the extent and frequency of such tasks should be reached between the user, owner and the Building Regulation enforcement authority at the stage when Building Regulation consent is being sought.

Copies of all reports prepared by the competent persons following each inspection, survey or structural appraisal (including a record of any remedial work undertaken) should be attached to the *Management Document.*

Regular inspections

There should be regular inspections of the installation by a competent person to verify:

- that the imposed loading on the platform does not exceed the designed use and loading limitations as stated on the *Loading Notices*;
- that the general condition of the structure has not markedly altered since being commissioned;
- that the *Loading Notices* are in a satisfactory condition and are securely displayed at suitable locations on the structure.

The competent person should notify the user of the installation of any signs of distress or deterioration of the facility which may warrant the platform floor being wholly or partly decommissioned and/or the procurement of a structural appraisal by an appropriately qualified and experienced person.

The frequency of inspections depends on the intended use of the structure but should be at least monthly.

Annual condition survey

A condition survey should be carried out annually by a competent person who is not also appointed to undertake regular inspections of the same installation. Its purpose is to:

- Determine whether the installation is in a satisfactory condition, taking into account its current usage, and to recommend any necessary routine maintenance work. Particular attention should be given to the state of the decking material and the guarding as well as the condition of any light cold-formed steel supporting beams. Any apparent sign of structural distress (including concern about movement and vibration of the facility during use) should be reported and a structural appraisal commissioned.

Structural appraisal

A structural appraisal of the installation should be undertaken by a competent person every three years, or other such interval as deemed appropriate for the particular use of the installation. Its purpose is to:

- Ascertain whether the condition and structural integrity of the installation is consistent with the original design assumptions and that the structure is adequate for its intended future use.

Where significant deterioration or damage of the structural fabric is evident, a detailed structural design check should be carried out to ascertain the implications of such defects on the continued performance of the structure; they should be reported to the owner or user of the facility accordingly. The report should outline any remedial works necessary to safeguard the future use of the structure for the intended purpose.

Further reading

British Standards Institution

BS EN 312:- Particleboards
Part 5: Requirements for loadbearing boards for use in humid conditions
Part 7: Requirements for heavy-duty loadbearing boards for use in humid conditions

BS EN 1195: 1998 Timber structures. Test method. The performance of structural floor decking

DD ENV 1995 - Eurocode 5: Design of timber structures
DD ENV 1995-1-1: 1994 General rules and rules for buildings (together with UK National Application Document)

European Committee for Standardization. Draft prEN 12369: Wood based panels. Characteristic values for established products. 1996

BS prEN 12871: 1998 Wood based panels. Performance specifications and requirements for loadbearing boards for use in floors, walls and roofs

BS 5268:- Structural use of timber
Part 2: 1996 Code of practice for permissible stress design, materials and workmanship

BS 5395:- Stairs, ladders and walkways
Part 3: 1985 Code of practice for the design of industrial type stairs, permanent ladders and walkways

BS 5669:- Particleboard
Part 5: Code of practice for the selection and application of particleboards for specific purposes

BS 5950:- Structural use of steelwork in building
Part 1: 1990 Code of practice for design in simple and continuous construction: hot rolled sections

BS 6180: 1995 Code of practice for barriers in and about buildings

BS 6399:- Loading for buildings
Part 1: Code of practice for dead and imposed loads

BS 7916: 1998 Code of practice for selection and application of particleboard, oriented strand board (OSB) , cement bonded particleboard and wood fibreboards for specific purposes

In the future .....

The guidance in this Digest was prepared following substantial consultation with manufacturers, designers, controllers and users. We intend to update it in due course to take account of experience gained from its use and any changes in the availability or specification of component materials.

The sponsor of this guidance, The Department of the Environment, Transport and the Regions, would welcome comments from users of this guidance. Please send your comments to:

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