INTERNATIONAL STANDARD

ISO 9194

First edition
1987-12-15

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION
ORGANISATION INTERNATIONALE DE NORMALISATION
МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ

Bases for design of structures — Actions due to the self-weight of structures, non-structural elements and stored materials — Density

Bases de calculs des constructions — Actions dues au poids propre des structures, des éléments non structuraux et des matériaux entreposés — Masses volumiques

Reference number
ISO 9194 : 1987 (E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 9194 was prepared by Technical Committee ISO/TC 98, *Bases for design of structures.*

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

Bases for design of structures — Actions due to the self-weight of structures, non-structural elements and stored materials — Density

0 Introduction

General principles on reliability of structures are given in ISO 2394.

Since at the moment, only insufficient statistical data of densities are available, the values given in this International Standard are deterministic ones. In general they may be interpreted as mean values of densities.

Even these mean values are in some cases different for the same material from one country to another. This is the reason for giving a range of two values for one material in this International Standard.

Each country in its relevant standards should use its traditional values which are in the indicated range.

1 Scope and field of application

This International Standard defines the actions due to the self-weight of structures, non-structural elements and stored materials. It gives the numerical values of their densities.

These actions are to be determined by multiplying the densities by the gravitational acceleration and by the actual volume. The actions caused by the weight of the earth placed on the structures are similarly calculated.

2 Reference

ISO 2394, *General principles on reliability of structures*.

3 General

3.1 The most important value in determining actions due to the self-weight of structures, non-structural elements and/or that of stored materials is the density.

3.2 For materials having all three dimensions of the same order of magnitude, the densities are expressed in kilograms per cubic metre (kg/m^3). For roofings (sheeting materials) having one dimension of smaller order of magnitude than the other two dimensions, the similar quantity will be surface density, expressed in kilograms per square metre (kg/m^2) (mass related to surface area).

3.3 In some countries roofings are considered to be external load, causing pressure on the structure (by analogy with, for example, snow load) — consequently these are expressed in newtons per square metre (N/m^2) or in pascals[1)].

For this reason, roofings (see annex A) are given as surface pressures, together with the values of surface density.

3.4 Densities of stored materials substantially depend on how they are placed. Usually two methods of stocking are distinguished :

a) disorderly storage of materials;

b) orderly storage of materials.

Disorderly or bulky stored materials are stored without bales, forming a natural heap. Orderly stored materials are stored in stocks or piles with or without bales.

4 Density values

4.1 The representative value of the density of materials and/or components of structures, non-structural elements and stored materials is in general determined by the mean value.

The representative value is generally represented by a unique value. In actual design situations, densities may alter due to the difference in quality of workmanship, moisture content, etc. The representative value of the density of earth is represented in the same manner, bearing compactness in mind.

4.2 The representative values of densities of structures and non-structural elements are given in a table in annex A; the representative values of densities of stored materials and densities of earth placed on structures are similarly given in annex B.

4.3 Where the tables give only one density value for one material (or soil), this means that the corresponding nominal values do not normally differ significantly (up to ± 5 %) in dif-

1) 1 Pa = 1 N/m^2

ferent countries and the indicated mean value is the average of the nominal values. The range of two values of densities given in the annexes for one material indicates that the mean values of densities for different countries vary between the indicated ones.

This also refers to the angles of repose. However, it should be emphasized that in accordance with the national practice of different countries, angles of repose differ up to ±30 % from those indicated in annex B. Thus values of angles of repose given in annex B are approximate.

4.4 For the time being, only limited statistical data are available and the values given in annexes A and B are based on relevant national practice.

Annex A

Representative values of densities of structural and of non-structural elements

(This annex forms an integral part of the Standard).

This annex gives representative values of the densities of structural and non-structural elements in the form of a table.

Material	Density kg/m³
Wood and substitutes[1] (air-dried, about 15 % humidity)	
Hardwood	
Beech tree (*Fagus sylvatica*)	680
Oak tree (*Quercus*)	690
Peduncular oak (*Quercus robur*)	640
Brazilian rosewood (*Dalbergia nigra*)	800
Turkey oak (*Quercus cerris*)	640 to 770
Yew tree (*Taxus baccata*)	640
Australian hardwood	
Box, grey (*Eucalyptus microcarpa*)	1 120
Penda, brown (*Xanthostemon chrysanthus*)	1 120
Softwood	
Black pine (*Pinus laricio*)	570
Larch tree (*Larix decidua*)	550
Norway spruce (*Picea*)	430
Spruce fir (*Pinus eccelsa*)	380 to 440
Scotch pine (*Pinus silvestris*)	490
White willow (*Salix alba*)	330
Giant poplar (*Populus alba*)	410
Trembling poplar (*Populus tremula*)	450
Ocume (*Ocume*)	410
Conifers	400 to 600
Extruded chipboard	500 to 750
Fibreboard	
hard	900 to 1 100
medium-hard	600 to 850
porous insulating	250 to 400
Plywood	750 to 850
Coreboard	450 to 650
Natural building stones	
Magmatic plutonic rocks	2 650 to 3 000
Magmatic vulcanites	2 500 to 2 850
Volcanic tuffs	1 400 to 2 000
Sedimentary rocks	
sandstone	2 700
marl	2 300
porous limestone	1 700 to 2 200
fresh-water limestone	2 400
compact limestone	2 650 to 2 800
dolomite	2 800
Transformed rocks	
clay slate	2 600
marble	2 700

Material	Density kg/m³
Building bricks and blocks	
Solid burnt clay brick	
up to 14 MPa (inclusive) compressive strength	1 600
over 14 Mpa compressive strength	1 800
Perforated brick (holes through the brick exceed 25 % of its volume)	
hollow brick	820 to 1 350
perforated brick	1 150 to 1 450
Lime-sand brick	1 700
Cob brick, adobe	1 600
Refractory brick for general purposes	
fireclay	1 850
high-strength fireclay	2 100
silica (dinas)	1 800
magnesite	2 800
chrome magnesite	3 000
corundum	2 600
Covering bricks	
inside wall-covering	1 600
outside façade covering	1 800
clinker brick	2 000
Gas silicate block	
with 2 MPa compressive strength	500
with 5 MPa compressive strength	700
with 7,5 MPa compressive strength	900
Acid-resistant brick	2 000
Tuff block with 5 MPa compressive strength	1 100
Glass brick, double-walled	870 to 1 100
Mortars	
Lime mortar	1 200 to 1 800
Lime cement mortar	1 750 to 2 000
Cement mortar (with 2,5 MPa or greater compressive strength)	2 100
Rock floor mortar	1 600
Gypsum mortar	1 200 to 1 800
Fireclay mortar	1 900
Pearlite mortar	
lime	340
gypsum	370
cement	440
Bitumen mortar with river sand	1 700
Concrete[2]	
Gravel concrete	2 250 to 2 500
Basalt concrete	2 300 to 2 500

Material	Density kg/m³
Crushed rock concrete	
C3-C35	2 300 to 2 500
Blast furnace foam slag concrete	
C3-C10	1 600 to 1 900
Aerated and gas concrete	
C1,5-C5	600 to 1 500
Expanded clay gravel concrete	
C1,5-C16	700 to 1 700
Perlite concrete	
C1,5-C2	350 to 700
Tuff concrete	
C3-C6	1 400 to 1 600
Lightweight aggregate concrete using sintered pulverized fuel ash aggregates	1 600 to 1 850
Heat insulating gas concrete	300 to 900
Heat insulating pearlite brick and pipeshell	260
Aggregates and fillers	
Sand	1 550
Sand gravel of 0 to 40 mm grain size	1 700
Gravel	1 500 to 1 600
Blast furnace foam slag	1 700
Blast furnace slag, granulated	1 200
Crushed slag stone of 5 to 40 mm grain size	1 500
Aerated silicate	1 000
Pulverized fuel ash (pozzolan) for use as a cementitious component in concrete (bulk density)	800 to 1 050
Lightweight concrete aggregate (Lytag) (bulk density)	750 to 1 000
Lightweight aggregate using sintered pulverized fuel ash/natural sand	1 700 to 2 000
Masonry from natural stones	
Rocks of initial setting	
basalt malphir, diorit, gabbro	3 000
basalt lava	2 400
diabase	2 900
granite, syngenit, porphyt	2 800
trachyt	2 600
Sedimentary rock	
graywacke, sandstone, puddingstone	2 700
dense limestone, dolomite, shell limestone and marble	2 800
limestone conglomerate (e.g. travertin, etc.)	2 600
volcanic tuff	2 000
Transformed rocks	
gneiss, granulite	3 000
slate	2 800
serpantine	2 700
Brick masonry[3)]	
Ordinary brick	1 500
Solid burnt clay brick	
up to 14 MPa (inclusive) compressive strength	1 500 to 1 700
over 14 MPa compressive strength	1 900
Walls made from brick with holes or ceramic blocks (depending on the type of brick and blocks used)	1 150 to 1 450
Tuff concrete, medium size building block	1 200
Gas silicate, medium size building block	
1,5 to 2,5 MPa compressive strength	600 to 800
2,5 to 5 MPa compressive strength	800 to 1 100
5 to 10 MPa compressive strength	900 to 1 300
10 to 20 MPa compressive strength	1 000 to 1 600
Inside wall-covering brick	1 700
Outside façade brick	1 900
Clinker brick	2 000
Fireclay brick (in fireclay mortar)	2 000
Acid-resistant brick (in bitumen mortar)	1 900
Glass brick, double-walled (in cement mortar)	1 100
Glass brick, coupled on one side (in cement mortar)	870
Metals for structures	
Structural steel	7 850
Cast iron structure	7 100
Aluminium	2 700
Covering and other building material	
Asphalt, pure	2 200
Bitumen	1 000 to 1 400
Tar (pitch)	1 100 to 1 400
Asbestos cement roofing and covering board	1 800 to 2 100
Asbestos cement corrugated board	1 600
Asbestos cement pipe	1 800
Cellulose acetate panel	1 300
Cement tile	2 400
Mosaic tile	2 200
Concrete flagstone	2 200
Tile	1 750 to 2 000
Face brick (hard façade brick)	2 500
Stoneware tile	2 400
Soft covering brick	
holed	1 350
solid	1 600
Epoxy resin	
without filler	1 150
with mineral matter	2 000
with fibreglass	1 800
Fenoplast	1 500
Rubber floor	1 800
Plastic tile	1 100
Polyamide (e.g. diamid)	1 100
Polyester resin, without filler	1 350
Polyethylene	930
Polyisobutylene-base board	1 350
Polymethylacrylate	1 150
Polypropylene	930
PVC hardboard	1 400
PVC flooring board	1 600
PVC flooring tile	1 700
Flat glass	2 600
Armoured glass	3 000

Material	Surface pressure N/m²	Surface density kg/m²
Roof shells, roofings 4)		
Tile roofings		
flat tile, burnt clay	380	38
pressed tile, burnt clay	480	48
flat tile, single roofing	350	35
flat tile, double roofing	700	70
flat concrete roofing tile	600	60
concrete tile, single roofing	400 to 500	40 to 50
Metal plate roofings		
galvanized steel plate (tin plate) roofing, 0,53 mm thick, folded or battened	40	4
double standing welt roofing from galvanized steel sheet roofing, 0,63 mm thick	55	5,5
zinc-plate roofing, 0,75 mm thick, welded	45	4,5
double-welt copper roof covering, 0,6 mm thick	60	6
aluminium sheet roofing		
0,6 mm thick	20	2
0,7 mm thick	25	2,5
lead-plate roofing, 2 mm thick, soldered	240	24
steel pantile roofing (galvanized)	150	15
sectional steel-plate roofing	75 to 240	7,5 to 24
Other plate roofings		
soft plastic roofing, 1 mm thick	90	9
bitumenized board roofing		
2 layer, nailed	80	8
3 layer with stuck gravel scattering	250	25
Asbestos cement corrugated board roofings or reinforced with other fibres		
standard roofing and corrugated board roofing	200	20
double board roofing	250	25
plastic corrugated board roofing, 1,5 mm thick	20	2
Smeared and scattered roofing		
plastic-bitumen roofing, 4 mm thick coating	50	5
synthetic glass roofing, 1 mm thick coating	60	6
flat glass roofing, 6 mm thick	200	20
armoured glass roofing, 6 mm thick	250	25
corrugated, armoured glass roofing, 6 mm thick	300	30
sectional glass roofing		
single	200	20
double	400	40

1) The body density of the wood should be increased by 120 kg/m³ where in a state saturated with water and by 80 kg/m³ in the case of a structure standing outdoors and not protected against atmospheric humidity.

2) For concrete grades (C), see ISO 3893 : 1977, *Concrete — Classification by compressive strength.*

The value of the density of reinforced concrete shall be that as given for the appropriate concrete increased by 100 kg/m³ where the reinforcement percentage is 1,25 or less. Appropriate adjustments shall be made for concrete reinforced to higher values.

3) The mass density of the masonry is taken without plaster but with mortar-filled voids. The mass density of concrete, light-weight concrete and reinforced concrete walls corresponds to the mass density value of the materials supplied.

4) The values do not include the fixing and supporting structures of the shell.

Annex B

Representative values of densities and angles of repose of stored materials

(This annex forms an integral part of the Standard.)

This annex gives the representative values of densities and angles of repose of stored materials in the form of a table.

Material	Density 1) kg/m³ natural heap 2)	Density 1) kg/m³ stack or pile 3)	Angle of repose degrees
Building and construction materials			
Basalt flagstone	—	2 750 to 3 000	—
Boulder clay	—	2 100	—
Brick sand, brick hardcore, brick chippings, moist earth	1 500	—	25 to 40
Cement	1 100 to 1 200	1 300 to 1 600	18 to 28
Clay			
fluorfine, dry	1 100	—	—
heavy, air-dried	1 600	—	—
Cork grit	—	60	—
Coke ash	750	—	25
Crushed foamed slag	900	—	35
Expanded clay gravel			
light	250	—	30 to 35
medium	400	—	30 to 35
heavy	550	—	30 to 35
Fibreglass	—	160 to 180	—
Foamed scoria, crushed, moist earth	1 000	—	35
Glass wool	—	100 to 110	—
Granite flagstone	—	2 600 to 2 800	—
Gravel and dry sand or moist earth	1 800	—	30 to 36
Heat-insulating gas concrete	—	500	—
Heat-insulating perlite brick	—	260	—
Heat-insulating perlite pipe shell	—	260	—
Lime hydrate	500	600	25
Lime			
lumps	850 to 1 300	—	45
ground	600 to 1 300	1 000 to 1 100	25
Limestone powder	—	1 300	—
Magnesite (caustic magnesite), ground	—	1 200	—
Mineral wool and derivatives	—	75 to 260	—
Plaster	1 000	1 100 to 1 500	25
Plastics			
polyethylene, polystyrol, granulated	—	650	—
polyvinylchloride, powdered	—	600	—
polyester resin	—	1 200	—
Perlite	—	70 to 250	—
Reed sheet of roofing	—	150 to 220	—
Powdered coal ash	900	1 000 to 1 200	25
Silt	—	1 800	—
Slag wool	—	200 to 300	—
Slag, granulated	1 100	—	30
Slaked lime	—	1 300 to 1 400	—
Trass, ground	—	1 500	—
Wood-wool	—	300 to 380	

Material	Density[1)] kg/m³ natural heap[2)]	stack or pile[3)]	Angle of repose degrees
Combustibles and fuels			
Coal			
mineral coal	900 to 1 200	—	30 to 35
coke	450 to 650	—	35 to 45
briquette			
egett	800	—	25
cornered coal	700	—	35
brown coal			
dry	800	—	35
moist earth	1 000	—	30
briquette	800	—	30
coke	1 000	—	40
brown coal dust	500	—	25
Charcoal	250	—	—
Oils			
fuel, diesel oil	800 to 1 000	—	—
crude oil	980	—	—
Petrol (gasoline)	750 to 800	—	—
Petroleum	800	—	—
Liquid gas			
propane	500	—	—
butane	580	—	—
Wood (air-dried, about 15 % moisture)			
hard wood			
chopped	400 to 600	—	45
logs	500	600 to 700	50
soft wood			
chopped	250	400	45
logs	300	400 to 600	—
fire-wood	400	—	45
Brush wood	—	200	—
Peat	300 to 600	500 to 900	—
Foodstuffs and agricultural products			
Alcohol	800	—	—
Barley	500 to 800	—	30
Barley in bags	—	650 to 750	—
Beer			
in tanks	1 050	—	—
in barrels	—	900	—
Butter			
in barrels	—	550	—
cased or boxed	—	500 to 800	—
Cocoa in bags	—	550	—
Coffee in bags	—	550 to 700	—
Clover-seed in bags	—	750	—
Conserves in bottles or boxes	—	800	—
Dry fodder			
baled	—	350	—
ensiled	1 000	—	—
Edible oil			
in barrels	—	750	—
bottled, in crates	—	550	—
Eggs in egg-stands	—	550	—
Fat, boxed	—	800	—
Fish			
in barrels	—	600	—
cased	—	800	—
Flax in bales	—	1 300	—
Flax-seed in bags	—	700	—