

ACTIONS ON STRUCTURES SELF-WEIGHT LOADS

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Actions on Structures

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The present report

This report describes self-weight loads and summarises those aspects that are considered to be important in their probabilistic modelling. It has not been the intention that the report should include detailed information on self-weight loads since this can be obtained from the literature. An extensive list of references has been included for this purpose.

The original draft of this report was prepared by M. Tichy. The report was then subjected to detailed discussion within the Commission.

Reports published up to June 1989

Self-weight loads, June 1989 (CIB Publication No. 115)

Live loads in buildings, June 1989 (CIB Publication No. 116)

PREFACE

The task of CIB Commission W81

The task of the Commission is to develop a set of stochastic models for actions which are mutually consistent and which can be used both in probabilistic design and analysis, and as a basis for deterministic models for actions.

This work will be described in a series of reports having a common general title "Actions on Structures". There will be one report dealing with general principles which are common for many kinds of actions and a number of reports each describing a specific action. Those under consideration are:

- Self-weight loads
- Live loads in buildings
- Dynamic loads in buildings
- Industrial loads
- Silo loads
- Loads in car parks
- Traffic loads on bridges
- Snow loads
- Wind loads
- Wave loads
- Ice pressure
- Climatic actions
- Impact loading
- Explosion loading
- Fire
- Earthquake

ABSTRACT

The calculation of the self-weight of a structure is assumed to be based on the product of the volume and the weight density of the material. Probabilistic models are presented for dimensions, for weight density and, as a simplification, for the self-weight per unit length (for linear members) or per unit area (for plane members). In this modelling, distinction has been made between systematic and random deviations from nominal values. A hierarchic model is described, which can be used to describe the variability within one component, between components produced under identical conditions and between all components of a larger population. The stochastic properties of the load effects are discussed. The uncertainties in the self-weight loads of components of different materials, such as concrete, masonry, steel and timber are treated. Measurements of self-weight loads are discussed and some examples of results concerning dimensions and weight density are given. Additional uncertainty sources (errors) may occur during design, production, construction and use. Research needs are mentioned.

KEYWORDS. Probabilistic models, dimensions, weight density, self-weight, random, stochastic, uncertainties, load effect.

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1 BASIC CONCEPTS

This report treats the weight of building components (structural or non-structural). It does not treat the weight of soil.

The load produced by *the self-weight of the structure* affects the structure throughout its lifetime without substantial changes. This load is an inherent property of the load carrying system and, consequently, it cannot be removed without changing the load carrying properties of the structure. Thus for this load the probability of occurrence at any arbitrary point in time is equal to 1.

The load produced by *the weight of non-structural components* may change during the lifetime of the structure due to repairs, reconstructions, modernizations, etc. Such changes may affect the magnitude of the load as well as its spatial distribution. At the time of design, it may be expected that such changes will occur, but the changes in magnitude and spatial distribution are generally not known. Removal of such components does not affect the general load carrying properties of the structure, but it may change the static equilibrium of the action-structure system. For the weight of non-structural components the probability of occurrence at any arbitrary point in time is smaller than 1. The weight of some types of non-structural components may also be treated as sustained live load (see the report on live loads in buildings). This is especially the case for intentionally demountable components as, for example, adjustable partition walls.

The weights of building components during construction should in some cases be treated as live load. This means that they should be assumed, at the design, to have a spatial distribution which may be unfavourable in comparison with the distribution valid for the completed building.

There is no sharp distinction between structural components which are considered to be parts of the load carrying system, and other components. In fact, most of the components carry some kind of load. From a formal point of view, the structural components

should be defined as those components which, according to the design calculations, are assumed to carry load. However, if the design is based upon data describing the properties of the actions and not upon some arbitrary classification, there is generally no need for a sharp distinction either between structural and non-structural components, or between self-weight and sustained live load.

The self-weight load of a structure may be derived from the equation

$$dG = \gamma dV \quad (1.1)$$

where dV is an infinitesimal volume element
 dG is the weight of this element
 γ is the weight density of the material

In general, the self-weight load can be assessed with reasonably good accuracy. Possible sources of uncertainty include

- fluctuations of the weight density of the material due to inhomogeneity of raw materials or production
- fluctuations of the dimensions
- fluctuations due to environmental factors, for example, variations of the humidity of the air which cause variations of the moisture content in the material.
- addition of unforeseen protective material (protective sheets, etc.)
- simplifications of the calculations of the weight of the components, for example, neglecting holes in a slab.

The sources, mentioned above, cause fluctuations of the self-weight which are partly random and partly systematic. The randomness is most pronounced for the first three of them.

2 PROBABILISTIC MODELS

2.1 Introduction

According to eq (1.1) the self-weight load can be calculated from the weight density of the material and the dimensions of the components. Thus, in principle, there is one probabilistic model for the weight density and one probabilistic model for the dimensions, including those which determine the shape of the components. These two models together constitute a model for the self-weight. However, in most cases these models are not specified separately but are directly combined to give one model which describes, for example, the weight per unit area of a slab, or the weight per unit length of a beam or a column.

Such a model should be regarded as a simplification, but its parameters contain all the information about dimensions and weight density which are necessary for the description of the self-weight.

2.2 A model for random behaviour of dimensions

A dimension of a building component can be expressed by

$$a = a_{\text{nom}} + \Delta a \quad (2.1)$$

where a_{nom} is the nominal value given in the design documents
 Δa is a deviation of a from a_{nom}

For a given population the deviation can be separated into a systematic component Δa_s and a random component Δa_r so that

$$\Delta a = \Delta a_s + \Delta a_r \quad (2.2)$$

This can also be expressed in a more general way using a hierarchic model. Then the deviations can be written

$$\Delta a = m + u + v + w(x, y, z) \quad (2.3)$$

where m is a general mean deviation for the whole population

u is a random variable which takes on one value for each group of units produced under identical conditions. The mean value of u is zero

v is a random variable which takes on one value for each individual unit. The mean value of v is zero.

$w(x,y,z)$ is a zero mean random field describing the variability of the dimensions within a unit

The application of this model can be illustrated by, for example, prefabricated concrete slab elements for which the thickness is the dimension of interest.

If a population consisting of one single slab is considered the systematic deviation is $m + u + v$ and the variability within the slab is described by $w(x, y, z)$.

For a delivery consisting of a number of slabs produced within a short time and under nominally identical conditions, the systematic deviation of the thickness is $m + u$ and the variability between the means of the thickness for the different slabs is described by v .

Finally for all slabs produced in the country the systematic deviation is m and the variability between the means of the thickness for the different slabs is described by $u + v$.

Of course, such a model can be extended in different ways, for example, by introducing a random variable describing the variability within a factory or by taking part of $w(x, y, z)$ as systematic (i.e., the slabs have, for example, an unintentional tendency to be thinner at the ends). In special cases the components of the expression (2.3) may be time dependent.

There is normally a correlation within the random field $w(x, y, z)$. The correlation between the values for the points (x_1, y_1, z_1) and (x_2, y_2, z_2) in the field normally decreases with increasing distance between the points.

In many cases the magnitude of $w(x, y, z)$ is small in comparison with u and v in eq (2.3). This is especially the case when the components are produced using some kind of machine, for example, when they are rolled or sawn. The influence of $w(x, y, z)$ on a load effect is often small due to the averaging filtering effect occurring when the load is transformed to load effect (compare section 3.1). Normally the influence of $w(x, y, z)$ becomes smaller if the volume of the component increases. However, in some special cases the influence of $w(x, y, z)$ can be important. An example of such a case is shown in section 3.2.

The magnitudes of the deviations are strongly dependent on the tolerances which are given for the dimensions and on the control executed in order to ensure that the tolerance limits are considered. However, in most cases tolerance limits and control are more important for the resistance and stiffness of a structural component than for its self-weight.

A hierarchic model can also illustrate the differences between the statistical properties for small and large populations. A small population may consist of components belonging to one single delivery or to one specific time interval of the production. Its statistical properties are associated with the production method. Sometimes upper and lower limits for the dimensions can be clearly recognized. A large population can, for example, consist of all components of a certain type produced within a country. Thus it is a mixture of a number of small populations. The mean of the mixture is the weighted average of the small population means with weights proportional to the respective population sizes. The variance of the mixture exceeds the weighted average of the small population variances by the weighted average of the squared deviations between the large population mean and the small population means. Upper and lower limits are not well defined even if one must assume that they exist.

Statistical parameters of the deviations of dimensions are given in section 5 for some types of structures or components.

2.3 A model for random behaviour of the weight density

The concept of nominal value is not so evident for the weight density as for the dimensions. However, in many cases it is possible to define a nominal value of the weight density as a value which characterizes the quality of the material (for bricks, light weight concrete and similar) or which is generally used in the calculation of the self-weight. Thus as for the dimensions the weight density of a material can be expressed by

$$\gamma = \gamma_{\text{nom}} + \Delta\gamma \quad (2.4)$$

where $\Delta\gamma$ is the deviation of the weight density from a nominal value.

As for dimensions, the deviation $\Delta\gamma$ can, for a given population, be separated into a systematic component $\Delta\gamma_s$ and a random component $\Delta\gamma_r$ so that

$$\Delta\gamma = \Delta\gamma_s + \Delta\gamma_r \quad (2.5)$$

Further, quite analogously to the treatment of dimensions, a hierarchical model can be applied to the variability of the weight density. This model describes the variability of the weight density within one component, between components produced under nominally identical conditions, and between components produced under different conditions. The example discussed in the previous section can also be applied to the weight density.

In some cases the weight density is time-dependent but this dependence is generally not important.

As for dimensions there is always a correlation between the weights densities at different points within a component.

The variability of the weight density is due to various factors, in the first place the structure of the material and its physical and chemical characteristics (absorptivity, hygroscopicity). For some materials (concrete, timber etc) a statistical relationship between the mean weight density and the mean strength exists.

The discussion in the previous section concerning the statistical properties of small and large populations can also, in principle, be applied to the weight density.

For some materials, values of statistical parameters of the weight density are given in section 5.

2.4 Random models for self-weight

The self-weight of a structural or non-structural component can be obtained by integrating eq (1.1) over the total volume of the component, i.e.

$$G = \int_{\mathcal{V}} \gamma \, dV \quad (2.6)$$

The volume $\mathcal{V}$ of the component is determined by its boundary $\mathcal{B}$ which in turn is determined by the dimensions of the component. Thus the uncertainty of G is a combination of the geometrical uncertainties of the boundary and the uncertainties of the weight density. However, in the design process the load effect due to the self-weight and not the self-weight itself is of interest. Load effects will be treated in chapter 3 and the more general and strict ways to combine uncertainties of dimensions and weight density will be treated in section 3.1.

In most cases the variability of the self-weight is relatively small and therefore it is possible to make simplifications, for example, according to the following.

For *one-dimensional components* (i.e. for beams, columns, and similar elements) with cross-section $\mathcal{A}$, the self-weight per unit length in the x -direction is

$$g(x) = \int_{\mathcal{A}} \gamma \, dA \quad (2.7)$$

where γ is the weight density, which varies randomly within the component and dA is the element area.

g , A and γ can be written

$$g(x) = \mu_g(x) + \Delta g(x) \quad (2.8)$$

$$A(x) = \mu_A(x) + \Delta A(x) \quad (2.9)$$

$$\gamma(x,y,z) = \mu_\gamma + \Delta\gamma(x,y,z) \quad (2.10)$$

The following relations are approximately valid

$$\mu_g = \mu_A \mu_\gamma \quad (2.11)$$

$$\Delta g(x) = \mu_\gamma \Delta A(x) + \mu_A \Delta \bar{\gamma}(x) \quad (2.12)$$

where $\Delta \bar{\gamma}(x)$ expresses the variability of the average value $\bar{\gamma}$ of γ over the mean cross-section i.e.

$$\Delta \bar{\gamma} = \frac{1}{\mu_A} E\left(\int_{\mathcal{A}} \gamma \, dA\right) - \mu_\gamma \quad (2.13)$$

where $E(\mathcal{A})$ is the expected cross-section of the area $\mathcal{A}$.

The variance of $g(x)$ is

$$\sigma_g^2 = \mu_\gamma^2 \sigma_A^2 + \mu_A^2 \sigma_{\bar{\gamma}}^2 \quad (2.14)$$

where

$$\sigma_{\bar{\gamma}}^2 = \sigma_\gamma^2 \frac{1}{A^2} \iint_{\mathcal{A}} \rho(y_1, z_1, y_2, z_2) \, dA_1 \, dA_2$$

ρ is the correlation function. $\rho = 1$ for $y_1 = y_2, z_1 = z_2$

In the same way, for *two-dimensional components* (i.e. for slabs, walls and similar elements) the self-weight per unit area in the x,y-plane is (t is the thickness).

$$g(x,y) = \int \gamma \, dz \quad (2.15)$$

where the integration is extended over the thickness interval at (x,y).

g, t and γ can be written

$$g(x,y) = \mu_g(x,y) + \Delta g(x,y) \quad (2.16)$$

$$t(x,y) = \mu_t(x,y) + \Delta t(x,y) \quad (2.17)$$

$$\gamma(x,y,z) = \mu_\gamma + \Delta \gamma(x,y,z) \quad (2.18)$$

In the same way as above

$$\mu_g = \mu_t \mu_\gamma \quad (2.19)$$

$$\Delta g(x,y) = \mu_\gamma \Delta t(x,y) + \mu_t \Delta \bar{\gamma}(x,y) \quad (2.20)$$

where

$$\Delta \bar{\gamma} = \frac{1}{\mu_t} \int \gamma \, dz - \mu_\gamma \quad (2.21)$$

The variance of g(x,y) is

$$\sigma_g^2 = \mu_\gamma^2 \sigma_t^2 + \mu_t^2 \sigma_{\bar{\gamma}}^2 \quad (2.22)$$

The equations (2.14) and (2.22) are valid if the variability of the dimensions and the variability of the weight density can be considered as uncorrelated, which is a reasonable assumption.

The variance $\sigma_{\bar{\gamma}}^2$ is in principle smaller than the variance σ_{γ}^2 . However, at least for concrete, wood and similar material, σ_{γ} has to be determined on test specimens of reasonable size and therefore the difference between σ_{γ} and $\sigma_{\bar{\gamma}}$ ought to be small in most cases.

A hierarchic model analogous to that defined by eq(2.3) can be applied to describe the variability of the self-weight within one component, between components produced under identical conditions and between components produced under different conditions. The random variables and the random field (given by eq(2.3)) can be estimated from the statistical properties of the dimensions and the weight density as shown above.

There is always a correlation within the random field which describes the variability of the self-weight within a component. It can be expressed by the autocorrelation function, the value of which normally decreases with the distance d between the two points for which the correlation is studied. A possible expression for the autocorrelation function may be

$$\rho(d) = \exp\left(-\frac{d^2}{c^2}\right) \quad (2.23)$$

where c is a correlation length.

In principle, c can be determined from the correlation lengths for the dimensions and the weight density. However, knowledge about the magnitude of c is not yet sufficient and therefore c has to be estimated by judgement, which might be done directly for the self-weight. Sometimes the correlation in a slab is different in the x - and y -directions. Then d and c are substituted by their components

$$d_x, d_y \text{ and } c_x, c_y \text{ so that } d^2/c^2 \text{ is substituted by } d_x^2/c_x^2 + d_y^2/c_y^2.$$

If the probability distribution functions for the dimensions and for the weight density are assumed to be Gaussian, the probability distribution function for the self-weight will not be Gaussian. However, if the random deviations are small compared with the mean values the Gaussian distribution function can be used also for the self-weight without great discrepancies.

3 LOAD EFFECTS

3.1 Principles

Generally it is the load effect and not the load itself that is of interest in the design. The load effect S can be written (compare eq(2.6))

$$S = \int_{\mathcal{V}} I \gamma \, dV \quad (3.1)$$

where I is the influence function for the load effect which is studied

$\mathcal{V}$ is the volume described by the boundary of the component.

The weight density γ and the volume $\mathcal{V}$ of the component are assumed to be mutually independent. Further the integral of the fluctuations of γ over the fluctuation of $\mathcal{V}$ is neglected. Thus, with

$$\gamma = \mu_\gamma + \Delta\gamma$$

$$\mathcal{V} = \mathcal{V}_0 + \Delta\mathcal{V}$$

where $\mathcal{V}_0$ refers to the nominal dimensions, eq (3.1) can be written

$$S = \mu_s + \Delta S \quad (3.2)$$

$$\mu_s = \int_{\mathcal{V}_0} I \mu_\gamma \, dV \quad (3.3)$$

$$\Delta S = \int_{\mathcal{V}_0} I \Delta\gamma \, dV + \int_{\Delta\mathcal{V}} I \mu_\gamma \, dV \quad (3.4)$$

This fairly general approach can be developed further. See [9].

3.2 Simplified model

In the same way as was shown in section 2.4, the expressions for the load effect can be simplified. Thus for one-dimensional components (length = L) with the self-weight $g(x)$ per unit length in the x -direction the load effect S can be written

$$S = \int_0^L I g(x) dx \quad (3.5)$$

L is not assumed to be random.

The mean and variance of S are

$$\mu_s = \int_0^L I \mu_g dx \quad (3.6)$$

$$\text{Var } S = \sigma_g^2 \int_0^L \int_0^L I(x_1) I(x_2) \rho(x_1, x_2) dx_1 dx_2 \quad (3.7)$$

where σ_g is the standard deviation of g . σ_g is assumed to be constant over the length L .

ρ is the correlation function with $\rho = 1$ for $x_1 = x_2$.

In the same way the load effect for a two-dimensional component, with the self-weight $g(x,y)$ per unit area, is

$$S = \int_{\mathcal{A}} I g(x,y) dA \quad (3.8)$$

where $\mathcal{A}$ is the set of points of the component. The area of $\mathcal{A}$ is A .

$\mathcal{A}$ is not assumed to be random.

The mean and variance of S are

$$\mu_s = \int_{\mathcal{A}} I \mu_g dA \quad (3.9)$$

$$\text{Var } S = \sigma_g^2 \int_{\mathcal{A}} \int_{\mathcal{A}} I(x_1, y_1) I(x_2, y_2) \rho(x_1 y_1, x_2 y_2) dA_1 dA_2 \quad (3-10)$$

An application of eq (3.6) and eq (3.7) is shown in FIG 3.1 and 3.2. FIG 3.1 shows a simple system consisting of a column and two cantilever beams of equal lengths. Both the beams have the same and constant nominal cross-section. The bending moment, M , in the section A-A of the column is studied.

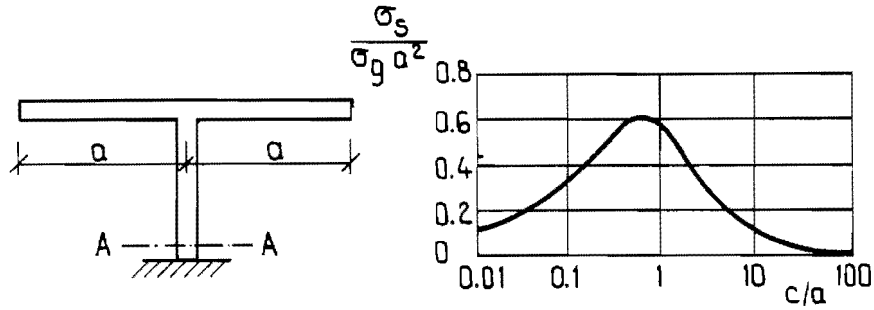


FIG 3.1

FIG 3.2

The mean value μ_s and the standard deviation σ_s of M are calculated according to eqs (3.6) and (3.7) and with the assumption that the correlation function is according to eq (2.23). The result of the calculation is shown in FIG 3.2 where $\sigma_s/(\sigma_g a^2)$ is given as a function of c/a . If c approaches infinity i.e. ρ approaches 1 (full correlation), the fluctuations of M , quite naturally, approach zero. For moderate values of c , σ_s has a definite value and a moment occurs in section A-A, the mean value of this moment being of course zero. A more elaborated study of this kind of problems is given in [9].

The example above is chosen because it is simple and not because it is common. It illustrates a type of problem which occurs in some cases, for example, for arches with large spans, for the part with zero moments in prestressed concrete beams, etc.

4 SELF-WEIGHT LOAD OF VARIOUS STRUCTURES

In this chapter the variability of the self-weight load of various structures will be discussed. Random as well as systematic deviations are treated but no sharp distinction can be found between the two types of deviations, at least not in practice. From a modelling point of view all the deviations are treated as random with the systematic part included partly in the mean values and partly in increased variances. Some of the systematic deviations are caused by simplifications and can be eliminated if the calculation of the self-weight is based on more precise and detailed assumptions.

4.1 Concrete structures

The factors which determine the self-weight of a concrete component include the cross section dimensions, the weight density of concrete, weight of reinforcement, weight of steel details, etc. The random deviations are mainly caused by the random variability of the dimensions and the weight density of concrete. The systematic deviations may, for example, be caused by a difference between the quantity of reinforcement used for a component and the quantity assumed at the design or by deviations in moisture content.

Further, deviations due to a systematic aberration of the bulk density of the aggregates at a certain locality may be encountered. In a national sample such deviations may be regarded as random.

As a rule, the self-weight of a concrete component is a substantial part of the total load.

4.2 Masonry structures

The factors determining the self-weight of a masonry structure include

- the dimensions of bricks or blocks
- the bulk density of bricks or blocks (depending on the weight density of the burnt clay and on the voids)
- the property of the mortar
- the pattern of the masonry and the thickness of the joints
- the extent of mortar penetration into voids
- moisture content.

The random deviations are mainly associated with the first three of these factors. The thickness of single joints may be random but the average thickness for a reasonable area ($\approx 1\text{m}^2$) of a masonry wall has small variability. Systematic deviations may occur in all factors. The last two factors are in most cases not considered but are important since

- the weight of the mortar penetrated into voids of cellular bricks amounts to about 5% of the volume of the voids
- the moisture content amounts in the production state to 8–15% of the weight of the masonry and in the dried state, after about 5 years, to 3–5% of its weight.

The significance of the self-weight of a masonry structure is almost always substantial.

4.3 Metal structures

The factors determining the self-weight of a metal structure include the weight of the individual parts and components, and the weight of connecting means.

The random deviations are mainly associated with the variability of the dimensions (material thickness). In comparison with random deviations of structures of other materials the random deviations of the self-weight of metal structures are generally small since

- the weight density of metal is practically constant
- the components of metal structures are made of various parts with different cross-sections which have a favourable influence on the self-weight variability.

The systematic deviations originate primarily from the design. The deviations due to a simplified design procedure (for example, a rough estimation of the weight of connecting means) can be eliminated by an accurate analysis.

The self-weight of a metal component is often small compared with the imposed loads carried by that component.

4.4 Timber structures

The factors determining the self-weight of a timber structure include

- the weight density of the timber
- the dimensions of the individual parts
- the weight of connecting elements
- the weight of metal parts of the structure (tie rods, etc.)
- moisture content

The random deviations are essentially associated with the first two of these factors. Systematic deviations are generally caused by simplifications in the design calculations.

The self-weight of a timber component is generally of importance since timber structures are often designed to carry relatively low loads.

5 MEASUREMENTS OF SELF-WEIGHT LOAD

The direct measurement of self-weight by weighing structures or members is exceptional, being used in practice only when verifying the values obtained by indirect ways or the values assumed in the design. Sometimes, direct measurement is used in the case of components of which structural members are made: rolled steel members, bricks, etc.

Indirect determination of the self-weight of single-component members and of their random characteristics is based on the investigation of the quantities of eq(1.1):

The *weight density* is determined by weighing material samples, the volumes of which have been determined by measuring the dimensions of the particular specimens. Table 1 contains some information about the weight density of building materials. The values in the table should be regarded as normal values which can be used if no specific information is given. In special cases the values of the weight density may have fairly large deviations from the values given in the table depending on local circumstances or special production procedures.

The *volumes* of the members are ascertained, as a rule, from their dimensions. Since the primary quantities used for the determination of load effects are the loads referred to unit length (for linear members) or unit area (for plane members), it is sufficient to measure only the cross-section dimensions. With reference to the determination of the self-weight load, the random variability of the lengths of members or overall areas of two-dimensional members may be neglected.

The *cross-section dimensions* are determined by the measurements on finished structures or members. Results from measurements of cross-section dimensions are given in Table 2 which contains the mean values (systematic deviations) and the standard deviations for the deviations from nominal values. The deviations depend to a great extent on the dimension tolerances given in the actual case. For structural members produced in a factory, they are usually smaller than the values given in the table.

In the case of multi-component members (e.g., composite steel and concrete beams) and in the case of members of heterogeneous materials (reinforced concrete, masonry, etc.) every component or material should be investigated separately.

Table 1. Mean value and coefficient of variation for weight density¹⁾

Material	Mean value kN/m ³	Coeff. of variation
<i>Concrete</i>		
Ordinary concrete ²⁾ $f_c = 20 \text{ MPa}$	23.5	0.04
40 Mpa	24.5	0.03
Lightweight aggregate concrete	} depends on mix composition and method of treatment	0.04–0.08
Cellular concrete		0.05–0.10
Heavy concrete for special purposes		0.01–0.02
<i>Masonry</i>	—	≈ 0.05
<i>Steel</i>	77	< 0.01
<i>Timber</i> ³⁾		
Spruce, fir (Picea)	4.4	} ≈ 0.1
Pine (Pinus)	5.1	
Larch (Larix)	6.6	
Beech (Fagus)	6.8	
Oak (Quercus)	6.5	

- 1) The values refer to large populations. They are based on data from various sources.
- 2) The values are valid for concrete without reinforcement and with stable moisture content. In case of continuous drying under elevated temperature the stable volume weight after 50 days is 1.0–1.5 kN/m³ lower.
- 3) Moisture content 12%. An increase in moisture content from 12% to 22% causes a 10% rise in weight density.

Table 2. Mean values and standard deviations for deviations of cross-section dimensions from their nominal values¹⁾.

Structure or structural member	Mean value	Standard deviation
<i>Concrete members</i> ²⁾		
$a_{\text{nom}} \leq 1000 \text{ mm}$	$0.003 a_{\text{nom}}$	$4 + 0.006 a_{\text{nom}}$
$a_{\text{nom}} > 1000 \text{ mm}$	3 mm	10 mm
<i>Masonry members</i>		
unplastered	$0.02 a_{\text{nom}}$	$0.04 a_{\text{nom}}$
plastered	$0.02 a_{\text{nom}}$	$0.02 a_{\text{nom}}$
<i>Rolled steel</i>		
steel profiles, area A	$0.01 A_{\text{nom}}$	$0.04 A_{\text{nom}}$
steel plates, thickness t	$0.01 t_{\text{nom}}$	$0.02 t_{\text{nom}}$
<i>Structural timber</i>		
sawn beam or strut	$0.05 a_{\text{nom}}$	2 mm
laminated beam, planed	≈ 0	1 mm

- 1) The values refer to large populations. They are based on data from various sources and they concern members with currently acceptable dimension accuracy.
- 2) The values are valid for concrete members cast in situ. For concrete members produced in a factory the deviations may be considerably smaller.

6 ADDITIONAL UNCERTAINTY SOURCES

Substantial differences between the actual and the assumed values of self-weight loads sometimes arise from sources other than those discussed above. They may occur in the design, construction, or use of the respective building or structure.

6.1 Deviations originating in the design

When determining the self-weight, deviations of its magnitude due to the following objective or subjective design errors may occur:

- Underrating the significance of the self-weight and, consequently, introducing an inadequate simplification of the calculation of its input values and resulting effects (particularly of long-term character). Overrating the significance may lead to better modelling which will reduce the possibility of large deviation.
- Estimates of insufficient accuracy of the values of initial variables: cross-section dimensions, weights densities, weights of partition walls and similar, particularly when not all data are known or available at the time of design.
- Neglecting some loads (e.g. loads due to haunches, plaster, sheet coverings, etc.).

6.2 Deviations originating during production and construction

In the manufacture, transport, erection, etc. of building components the following errors may occur:

- Deviations from specifications based on the design as far as materials are concerned (use of materials with weights densities deviating from the values used at the design)
- Deviations from dimensions specified on the basis of design calculations for reasons of production technology.
- Deviations caused by particular erection methods, for example, as a consequence of imprecise evaluation of the deformation and settlement of scaffolding or formwork in the case of cast in situ concrete structures.

The differences in self-weight load due to the shortcomings of construction are caused, in the majority of cases, by insufficient experience and control, insufficient knowledge and shortage of those materials required by the design.

6.3 Deviations originating in the use of the building

In the course of use of the building, self-weight loads do not change substantially (possibly with the exception of hygrometric and chemical changes) unless the function of the building has been modified by:

- Additions and reconstruction without sufficient evaluation of the effects of the self-weight of additional or removed components (harmful effects may occur because of increasing as well as decreasing loads), for example, uncontrolled additional bituminous layers on bridge decks.
- Failure of the function of some parts of the building, for example, long-term saturation of roofing materials by the leakage of water.

7 RESEARCH NEEDS

With regard to the contemporary needs for the design of common types of building structures the field of self-weight loads has been sufficiently investigated. Current engineering practice does not require the solution of any specific problems. From time to time, naturally, the need arises to determine the self-weight parameters of structures made from new materials.

Research in the field of self-weight of structural as well as non-structural components, however, is necessary to a certain extent in the areas concerned with the solution of more sophisticated reliability problems. In particular, the following problems have not yet been investigated:

- self-weight variability within one structure,
- effect of technological processes of production and execution on the self-weight of structures,
- effects of quality assurance measures
- evaluation of correlation data and effects,
- more sophisticated probability models.

8 REFERENCES

Only those references which treat subjects relevant to problems concerning the self-weight of building components have been listed. Some of the references treats dimensions of structural parts primarily from a resistance point of view but the content of these references can also be applied to self-weight problems. Papers which treat load in a more general way are listed in the report "Actions on Structures, General Principles".

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