Basis of design and actions on structures: part 2.1: densities, self weight, imposed loads

EUROCODE 1
Basis of Design and Actions on Structures
Part 2.1: Densities, Self Weight, Imposed Loads

Gerhard SEDLACEK
Professor Dr
RWTH Aachen
Aachen, Germany

Gerhard Sedlacek, born in 1939, is a Professor of Steel Construction at the RWTH Aachen. He is a member of the CEN/TC250 Co-ordination Group and is heavily involved in the production of the Structural Eurocodes.

Haig GULVANESSIAN
Professor & Civil Engineer
Building Research Establishment
Garston, Watford, Herts UK

Haig Gulvanessian, born in 1941, is a graduate of the University of London. He is Head of the Structural Design Division at BRE and a Visiting Professor at Imperial College, London. He is Technical Secretary of the EC1 Committee and Chairman of the CEN/TC250 Interim Ad-Hoc Group on Basis of Design.

Summary

This paper is divided into two parts. The first Part (Section 1) describes the background against which the Sections in ENV 1991-2-1 on Densities and Self Weight has been drafted and identifies some of the problems in achieving a fully harmonised code. The second Part (Section 2) describes the background of the choice of the loading models and numerical values for loads and roofs in the Section in ENV 1991-2-1 on Imposed Loads.)

1 ENV 1991-2-1 Sections on Densities and Self Weight

1.1 Introduction

In developing the Sections on Densities and Self Weight of ENV 1991-2-1, consideration was given to the contents of the National Codes of the CEN Member States and the International standard ISO 9194 [5].

There are however differences in the scopes and specifications of the codes of the CEN Member States relating to Self Weight and Densities of Building and Stored Materials. For example National Codes of particular countries provide considerable detail, with much of this detail based on comprehensive supporting Standards; while other countries off little guidance. Additionally the guidance that is available is at times somewhat contradictory. These differences have imposed restraints and limitations to the content of Eurocode 1: Part 2.1.

1.2 Scope and Field of Application

These Sections of ENV 1991-2-1 apply to the weight of

- materials used in construction;
- individual structural elements;
- parts of structures and of whole structures;
- some fixed non-structural items; and
- materials used in construction

As special cases, it also covers the weight of certain moveable light weight partitions, materials for bridge construction, services and earth and soil pressures. The code provides specific advice for the determination of the weight of the following structural elements; floor and walls, cladding and finishes and roofs.

The Code gives,

i) representative values for the Bulk Weight Densities of building materials;
ii) representative values for the Bulk Weight Densities for a range of stored materials relating to building and construction, agriculture, liquids, solid fuel and industry
iii) the angle of repose for particular stored materials; and
iv) methods for the assessment of the representative values of permanent actions due to gravity.

1.3 Basis of Bulk Weight Density Values

There is in general little statistical basis for the load values given in current National and International Codes and no new research has been carried out for this Eurocode. It is not therefore possible to describe the load values included in this Eurocode as either mean or characteristic values since both of these terms imply some understanding of the underlying statistical distribution of the load values. Loads in these sections of ENV 1991-2-1 are therefore described as representative values. For materials where the bulk weight density has significant variability according to its source a range of values is provided in the Code.

1.4 Evaluation of Actions due to Gravity

Unless more reliable data is available (ie. from product standards, the producer or by weighing), the Code recommends that the weights of individual elements (e.g. beams or columns) be estimated from their dimensions and the densities of their constituent materials; the weights of parts of the structures (e.g. whole floors or whole storeys) and of non-structural elements (e.g.plant) be determined from the weights of the elements of which they are composed. It recommends that dimensions used should be intended values of geometric properties (in general taken from the drawings).

For situations where more accurate values are required (e.g. where a design is likely to be particularly sensitive to variations in dead load) the code recommends that a representative sample of the materials to be used, at representative moisture contents, be tested.

When the self-weight of a component or element is likely to be significantly influenced by time-dependent effects (e.g. moisture, dust accumulation etc.) the code recommends that appropriate allowance should be made.

For certain situations the code recommends that upper and lower values for the permanent actions on structures should also be considered. Account shall also be taken of possible variations in the thickness of finishes; e.g. when the thickness depends on the deflection of the structural component to which the finish is applied. Examples of these situations are:

- thin concrete members
- when there is uncertainty about the precise value of the dead load; and
- where dimensional alternatives and the exact materials to be used remain open at the design stage.

1.5 Future Development

The draft being developed at the present time will be presented in a 'final' form to CEN/TC250/SC1, for submission for voting as a prENV by 31 January 1993.

In drafting the Code, a particular problem has been the lack of harmonised specifications and descriptions for many of the building and stored materials. CEN Standards on many of these items are expected to become available in the future and during the period leading to the transposition of ENV 1991-2-1 into an EN.

2. Imposed loads on buildings

2.1 Scope of ENV 1991- Part 2.1 Section 6

In the part "Imposed Loads on Buildings" of Eurocode 1 loaded floor and roof areas are divided into four classes according to their use

- areas in dwellings, offices etc.
- garages and vehicles traffic areas
- areas for storage and industrial activities
- roofs

The standard gives numerical values for the floor and roof loads in buildings including parking and vehicle traffic areas. For areas for storage and industrial activities only guidance for the determination of numerical values is given. The list of contents of the part "Imposed Loads on Buildings" can be taken from Figure 1.

Part 2.4 Section 6 Imposed Loads on Buildings

Figure 1: List of Contents of Part 2.4 "Imposed Loads on Buildings" of Eurocode 1

2.2 Areas of dwellings, offices etc.

For areas of dwellings, offices etc. the imposed loads depend on the type of occupancy, see Figure 2. The loads may be caused by

- furniture and moveable objects (e.g. light moveable partitions), loads from commodities the contents of containers.
  These loads are at certain points in time subjected to considerable instantaneous changes in their magnitudes, mainly due to change of occupancy or tenant, change of use etc. Between these instantaneous changes the load varies very slowly with time and the magnitudes of the variations are generally small, see Figure 2a.
- normal use by persons. These loads are often periodical and only present during a relatively small part of the time, e.g. for school rooms only about 1/4 of the day, as illustrated in Figure 2b. The proportion between the load caused by persons and the load caused by furniture depends on the type of locality. E.g. for residential buildings it is small, in theatres and on corridors it is great. In some cases the loads from persons may also cause dynamic effects, e.g. in dancing halls.
- extraordinary use, such as exceptional concentrations of persons or of furniture, or the moving or stacking of commodities which may occur during reorganization or

redecoration. These special situations occur during a short or moderate period of time, however sufficiently often during the lifetime of a building to make it necessary to take them into account, Figure 2c.

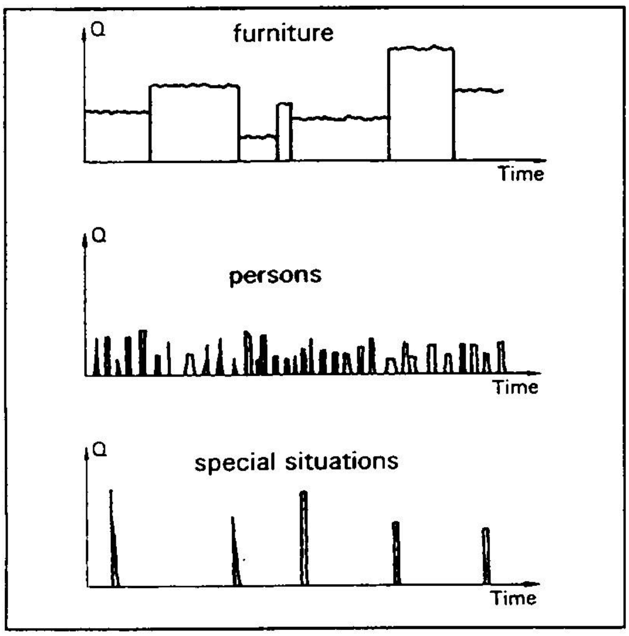

Figure 2:
Time variability of the load:
- Furniture and heavy equipment
- By persons in ordinary load situations
- Special load situations

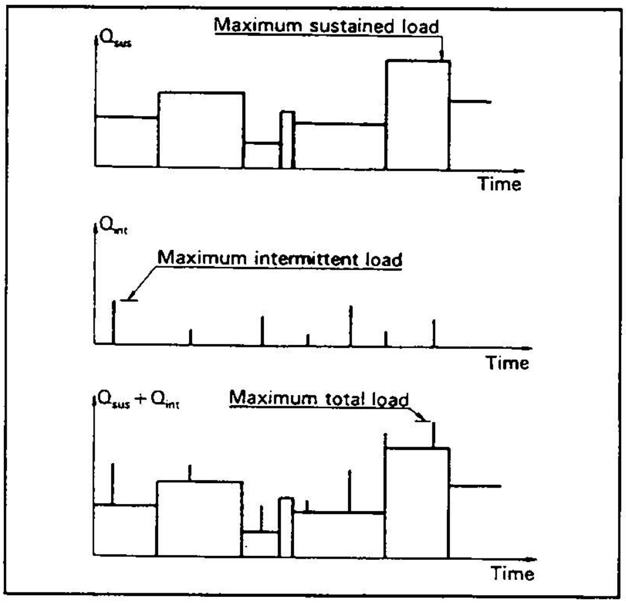

Figure 3:
Sustained load (Q_{sus}), intermittent load (Q_{int}) and total load as stochastic process representing the variability

In an attempt to determine the design values and the characteristic values of imposed loads on a statistical basis the following assumption have been made:

1. In principle for the description of imposed loads it appeared appropriate to consider separately the variation in space and the variation in time.
2. For the variation in space for practical reasons it is normally usual to represent the "per definition" discrete loads by means of an equivalent uniformly distributed load. This uniformly distributed load is dependent on the tributary area, and also on the static system of the component to be designed.
3. The variation in time is taken into account by modelling the load by two components:
   - a <u>quasipermanent (sustained) load</u>, Figure 3a, the magnitude of which represents approximately the time average of the real fluctuating load between the changes of occupancy, including herein also the weight of persons who are normally present. The magnitude of the fluctuations between the changes of occupancy will then be included in the uncertainties of the sustained load.

- an intermittentd loa, Figure 3b to represent all kinds of live load not covered by the sustained load, e.g. the loads due to extraordinary use.
  The combined sustained and intermittend live load is shown in Figure 3c.

4. To determine the design values a reference period of 50 years and a reliability index ß = 3.80 has been adopted and the characteristic values p_K were determined from the design values p_d by $p_k = p_d / \gamma_Q$ where γ_Q = 1.50 was used.

Unfortunately the statistical database for the determination of the characteristic values is rather poor; the numerical load measurements in the literature [ ] deal mainly with quasipermanent loads parts in some areas of representative use only, whereas little is known about quasipermanent loads in case of other types of use (e.g. warehouses, archives, libraries, tool sheds) and about short term loads, where estimations are necessary. Figure 4 gives some values determined in this way.

Imposed Load	Tributary area			
	m^2	p_k [kN/m²]	ψ_0	ψ_2
Office building	10	1,90	0,44	0,27
	50	0,95	0,68	0,50
Residental building	10	1,75	0,51	0,23
	50	0,87	0,69	0,32
Commercial building	10	2,10	0,45	0,14
	50	1,00	0,66	0,31
School	10	2,20	0,50	0,23
	50	1,30	0,67	0,37
Hotel	10	2,30	0,54	0,09
	50	0,90	0,72	0,26
Hospital	10	0,80	0,58	0,43
	50	0,55	0,31	0,56

Figure 4: Characteristic values and combination values determined on a statistical basis.

As the justification of all characteristic values on the basis of statistical data could not be reached, a more pragmatic way of deriving the load values was adopted in addition: they are derived from a comparison of the existing European national load regulations.

Figure 5 gives some examples from these comparisons. Figure 6 gives the the final proposals for the characteristic values of the uniformly distributed loads q_K and the combination factors y_i and for a concentrated load Q_K acting alone in dependance of the category on use of the floor.

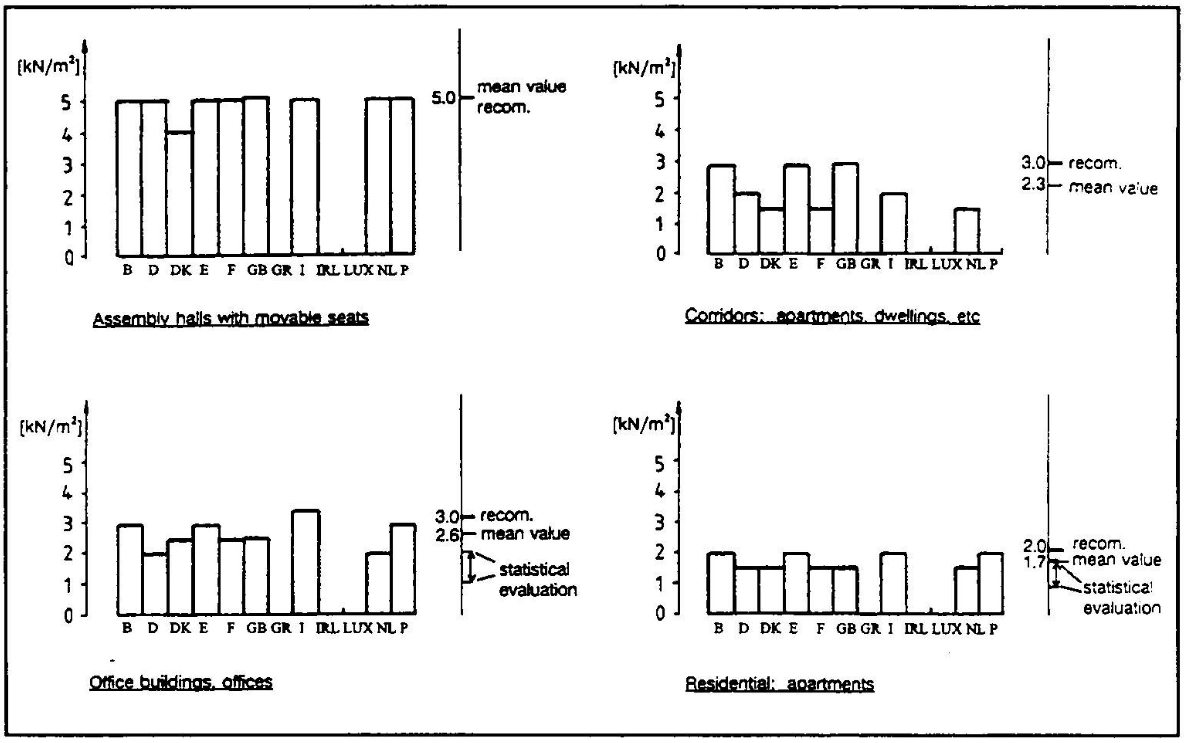

Figure 5: Comparison of European load regulations.

Loaded areas		q_k [kN/m²]	Q_k [kN]	ψ_0	ψ_1	ψ_2
category A (domestic and residential activities)	- general	2,0	2,0	0,7	0,5	0,3
	- stairs	3,0	2,0	0,7	0,5	0,3
	- balconies	4,0	2,0	0,7	0,5	0,3
category B (public buildings, offices, schools, hotels)	- general	3,0	2,0	0,7	0,5	0,3
	- stairs, balconies	4,0	2,0	0,7	0,5	0,3
category C (assembly halls, theatres restaurants, shopping areas)	- with fixed seals	4,0	7,0	0,7	0,7	0,6
	- other	5,0	7,0	0,7	0,7	0,6
category D (areas in warehouses, department stores)	- general	5,0	7,0	1,0	0,9	0,8

Figure 6: Imposed loads on floors in buildings

2.3 Garage and vehicle traffic areas

In general the quasipermanent imposed load part does not exist in parking garages. Schematic diagrams for the daily fluctuations of the total number of cars in car parks depending on the location may be taken from Figure 7. A propabilistic approach to determine the characteristic values of the uniformly distributed loads on parking areas may be based on the following assumptions:

- the spatial variability between different parking places which all are marked and have the same shape and magnitude in the whole car park is such that there is no correlation between the load values for the individual places and the same statistical data (Gaussian distribution) for the vehicle weights Q_i are valid for all of them.
- the temporal characteristics of the loads at the individual parking places are modelled by a rectangular wave renewal load process, see Figure 8, that can be defined by the busy time t_d (hrs per day) when the car park is occupied and the dwell time t_u when a specific parking place is occupied continuously by the same car. The mean number of cars per day is then t_d/t_u.

Design values and characteristic values calculated with these assumptions are given in Figure 9. These values have been used in defining the characteristic values and combination values in Part 2.4 of EC 1, which are given in Figure 10. By the simultaneous action of uniformly distributed and concentrated loads the influence of the tributary area has been taken into account.

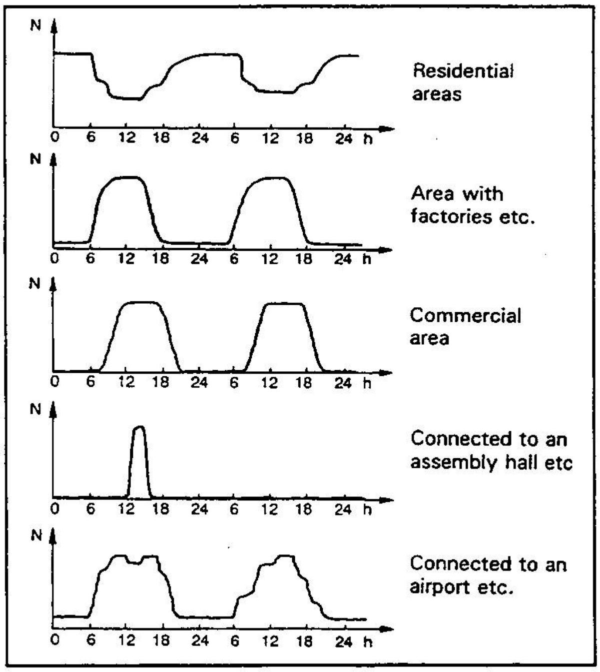

Figure 7: Schematic diagrams of the daily fluctuation of the total number of cars in car parks with different locations

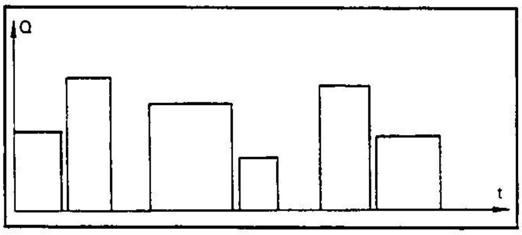

Figure 8: Rectangular renewal wave proces

Imposed load	Tributary area m^2	p_k kN/m^2	ψ_0
standard	10	4,00	0,55
	50	2,11	0,62
diagonal	10	3,55	0,54
	50	1,83	0,60
approach ways	10	2,19	0,84
	50	0,76	0,79

Figure 9: Characteristic values and combination values determined on a statistical basis

Traffic areas	q [kN/m²]	Q_k [kN]	ψ_0	ψ_1	ψ_2
category E vehicle weight: < 35 kN	2,0	20	0,7	0,7	0,6
category E vehicle weight: 35 kN-160 kN	5,0	85	0,7	0,5	0,3

Figure 10: Imposed loads on garages and vehicle traffic areas

2.3 Roofs

Numerical values for uniformly distributed loads and concentrated loads acting independently are given for the roof category, where the roof is not accessible except for maintenance, repair and cleaning, see Figure 11. These values have been derived from a comparison of national codes.

Roofs	q_k [kN/m²]	Q_k [kN]
Category G	0,75	1,5

Figure 11: Imposed load on roofs

2.5 Horizontal Loads on Partition Walls and Barriers due to Persons

For barriers or partition walls having the function of barriers, horizontal forces due to persons are given as shown in Figure 12. These values are not suitable for the design of railings in sports stadia.

Use of the loaded area	q [kN/m]
Category A Category B Category C and D	0,5 1,0 1,5

Figure 12: Horizontal loads in partition walls and barries due to person

2.6 Influence of the loading area

The influence of the loading area is taken into account in a different way for the loading area within one storey and for loading areas from several storeys. For loading areas within one storey the influence if any is modelled by the simultaneous action of an area independent uniformly distributed load and a concentrated load. For loading areas from several storeys (only relevant for areas with category A to D) a reduction factor

$$\alpha_n = \frac{2 + (n - 2)\ \psi_o}{n}$$

is used that is related to the number of storeys ($n > 2$) and the combination factor ψ_o.

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[4] Sentler, L: Live Load Surveys: A review with discussions, report 78 Lund, Sweden 1976

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