UNIVERSITY OF CAMBRIDGE

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MEICON

Minimising Energy in Construction

Demonstrating Floor Loading

Report

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EP/P033679/2
www.meicon.net

Demonstrating floor loading

"In every building, the floor shall be on sufficient strength to bear the weight to be imposed upon them, exclusive in all cases of the weight of material used in their construction"

The Laws of New York State 1860 [1]

"It was found that live loads assumed in designing many types of buildings were largely matters of tradition and had scant scientific basis."

Woolson at al. (1925) [2]

"Historically buildings have been designed for far higher loading than regulations require and beyond what they experience in practice. This over specification has become the norm based on perception in the market place that this provides a degree of flexibility."

BCO Guide to Specification 2014 [3]

1 Introduction

As part of the **MEICON** project an exercise was conducted to demonstrate what floor loading values really look like. It aims to help architects, structural engineers, clients, quantity surveyors and letting agents understand what the implications of design live load values really are.

Design codes introduce characteristic floor live load for different building typologies that include load from the occupants, furniture and other, considered as temporary. For office buildings characteristic floor live load according to codes varies between 2.0 and 3.0kN/m^2, with an average for 61 countries of 2.39kN/m^2 (https://www.meicon.net). Nevertheless, there is no clear definition of a characteristic value [4]. For office buildings at ground floor the live loads according to the Eurocode 1 National Annex for the UK are given as 3.0kN/m^2 [7].

In reality we find that office buildings are usually not designed for the minimum live load prescribed in design codes. Examining 95 office buildings competed in the last 20 years and located in the UK, US and Canada (6.3M square metres in total) we find that the area weighted average live load is 3.57kN/m^2 with an average allowance for partitions of 1.06kN/m^2 [8]. Half of analysed floor space was designed for 4.50kN/m^2 and one tenth for 5.00kN/m^2 or even more.

This report looks to examine and demonstrate what loads assumed in design calculations really look like, and if it is even possible to reach those values.

2 Floor loading experiment

An experiment was conducted on 29th January 2019 in a meeting room located in the James Dyson Building at the University of Cambridge Department of Engineering to examine what varying levels of floor loading really look like (Figure 1).

Figure 1 James Dyson ground floor meeting room (JDG-13) with capacity of 10 people

2.1 Methodology

The experiment was planned to be divided in two main parts. The first part was to find the floor load under normal use, with ten volunteers sitting by the table. Following this ten further volunteers were introduced to fill the space randomly. This part was planned to be completed either when room capacity is reached or there are no more volunteers.

The second part was to remove all furniture from the room and let into the room the number of volunteers whose weight will cause the floor load increase by a set amount each time. As 29 volunteers attended the experiment, this number defined the loading possible. All 29 volunteers were introduced into the space, and then asked to occupy floor space of known area to define a floor loading across this area. Each participant was weighed, and thus the floor loading over specific areas was determined. The room was divided into 8 areas of 9, 7.50, 6.75, 6.00, 5.25, 4.5, 3.75, 3.00m^2 (Figure 2).

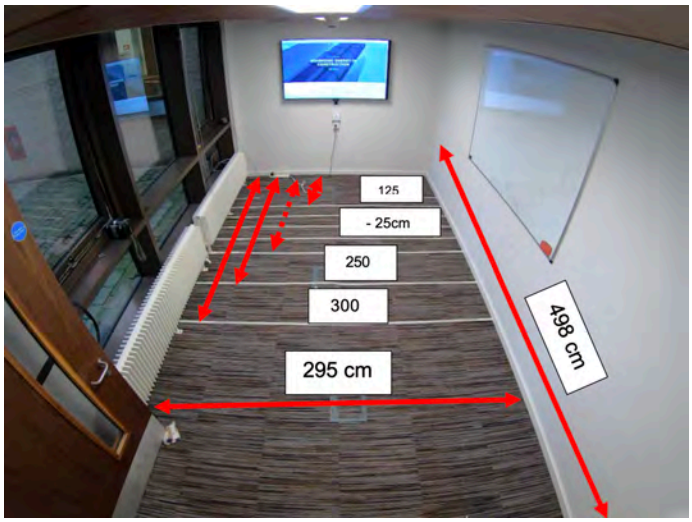

Figure 2 James Dyson ground floor meeting room (JDG-13) – room floor with smaller areas.

2.2 Room information

The meeting room is located in the James Dyson Building at the University of Cambridge Department of Engineering, and has dimensions of 4980 x 2950mm giving an area of 14.69m^2. In the central part of the room the table is situated with dimensions of 3600x100mm giving an area of 3.60m^2. Having a table in the centre, floor area is 11.09m^2. Meeting room normal in-use occupancy is 10 people.

2.3 Loading

Twenty-nine volunteers took part in the loading experiment. Each participant was weighed. The weight of all 29 volunteers was 2,125kg (20.85kN). The lowest weight was 50.9 kg and the highest 105 kg. The average was 73.3kg. To aid the experiment the room was divided into 8 smaller areas with an area of – 9, 7.5, 6.75, 6, 5.25, 4.5, 3.75 and 3.00m^2 (Figure 2), that represented 60, 50, 45, 40, 35, 30, 25 and 20% or original room area.

3 Results

3.1 Normal capacity – First part, first step

Room was filled with the normal capacity – 10 people sitting by the table. The live load (including all furniture) was found to be 0.54kN/m^2 (Figure 3).

Figure 3 JDG-13 – normal capacity – live load (including furniture) = 0.54kN/m^2 ()

3.2 Occupants capacity exceeded by 130% - First part, second step

Room was filled with 23 people sitting by the table and standing around. Capacity of the room was exceeded by 130%. The live load (including all furniture) was found to be 1.18kN/m^2 (Figure 4).

Figure 4 JDG-13 – Capacity exceeded by 130 % – live load (including furniture) = 1.18kN/m^2 (Table 1)

3.3 Filling the room – Second part

The second part of the experiment was to find what load might be caused by 29 volunteers, placing them on a decreasing floor area. The figures below show different floor area for the same number of people.

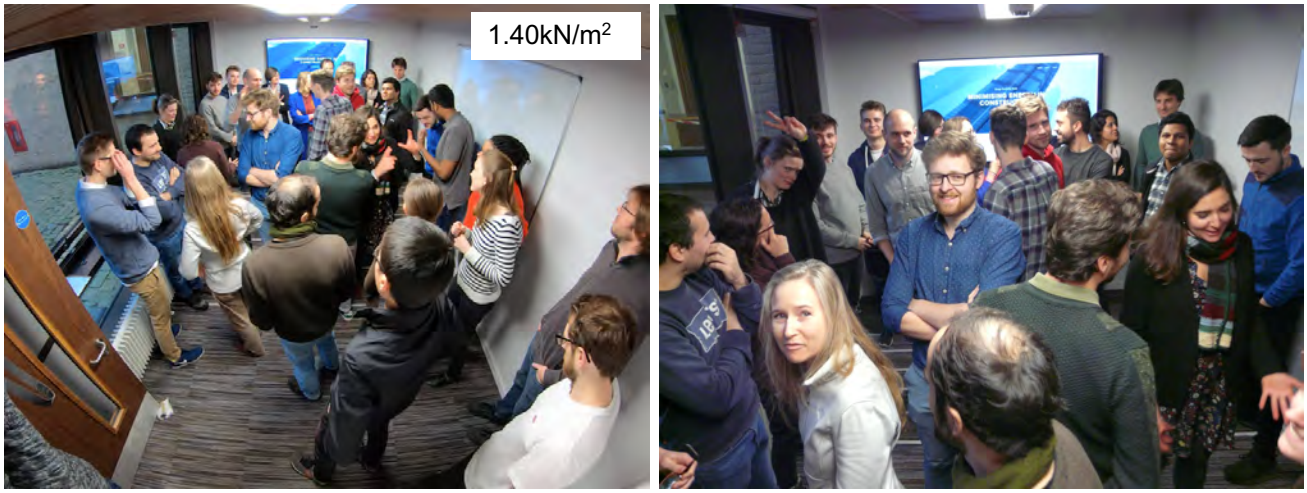

Figure 5 JDG-13 – 29 volunteers in 15m^2 = 1.40kN/m^2 (Table 1)

Figure 6 JDG-13 – 29 volunteers in 9m^2 = 2.3kN/m^2 (Table 1)

Figure 7 JDG-13 – 29 volunteers in 7.5m^2 = 2.8kN/m^2 (Table 1)

Figure 8 JDG-13 – 29 volunteers in 6.75m^2 = 3.1kN/m^2 (Table 1)

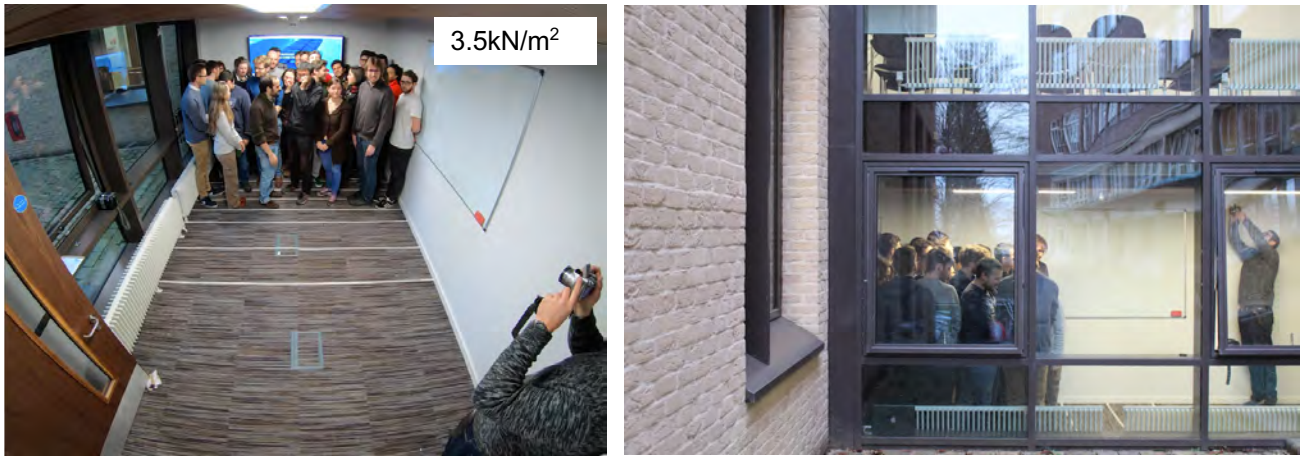

Figure 9 JDG-13 – 29 volunteers in 6m^2 = 3.5kN/m^2 (Table 1)

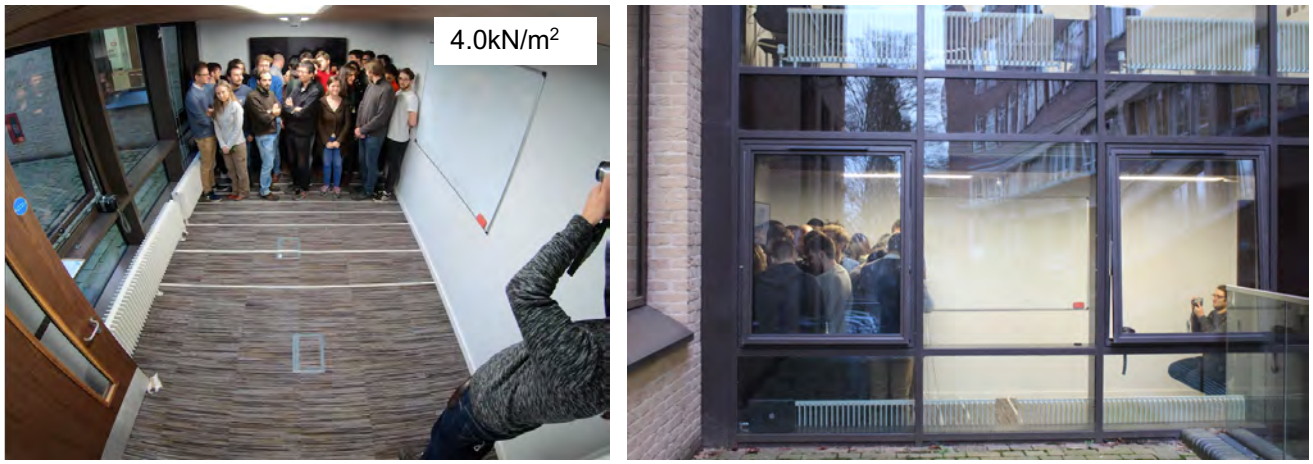

Figure 10 JDG-13 – 29 volunteers in 5.25m^2 = 4.0kN/m^2 (Table 1)

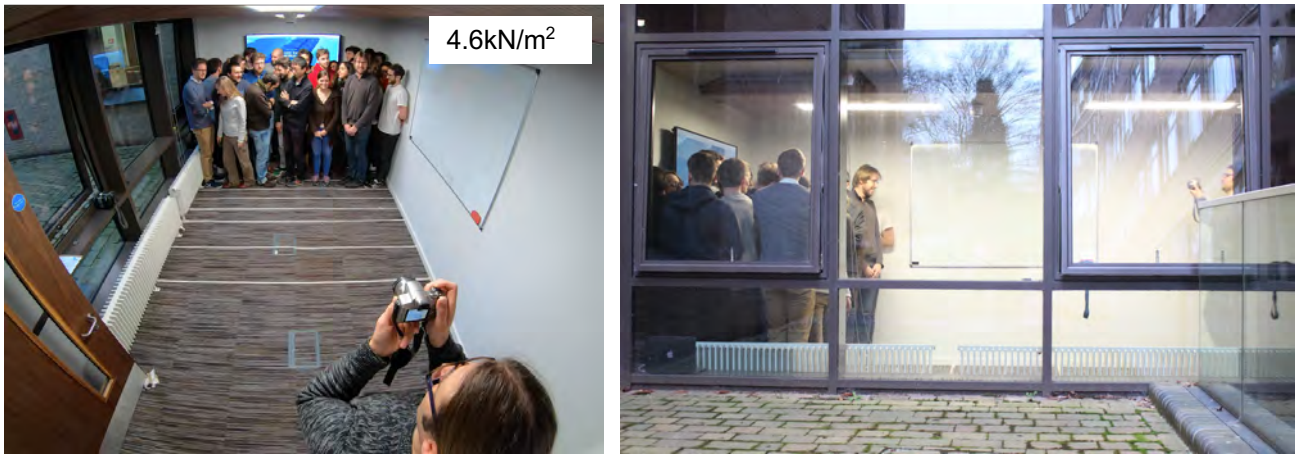

Figure 11 JDG-13 – 29 volunteers in 4.5m^2 = 4.6kN/m^2 (Table 1)

Figure 12 JDG-13 – 29 volunteers in 3.75m^2 = 5.6kN/m^2 (Table 1)

Figure 13 End of the experiment with load of 5.6kN/m^2 and 7.7 volunteers per 1m^2 (Table 1)

Table 1 Experimental results

Length [m]	Width [m]	Area [m^2]	% of the room	Person per m^2	Load [kg/m^2]	Load [kN/m^2]	Load [psf]	Cement bags per m^2	Comments
Normal capacity and with capacity exceeded by 130%									
5.00	3.00	15	100%	0.67	55	0.54	11.3	2.2	+ 10 chairs, 3 tables, one small table = 72kg
5.00	3.00	15	100%	1.53	121	1.18	24.7	4.8	+ 10 chairs, 3 tables, one small table = 72kg
Filling the room									
5.00	3.00	15.0	100%	1.93	142	1.39	29.0	5.7	-
3.00	3.00	9.0	60%	3.22	236	2.32	48.4	9.4	~EC1 min value - 2.0kN/m^2, http://bit.ly/2sXmeaY
2.50	3.00	7.5	50%	3.87	283	2.78	58.0	11.3	~EC1 NA UK, min value for floors above a ground floor - 2.5kN/m^2
2.25	3.00	6.75	45%	4.30	315	3.09	64.5	12.6	~EC1 NA UK, min value - for a ground floor - 3.0kN/m^2
2.00	3.00	6.0	40%	4.83	354	3.47	72.6	14.2	~ assumptions used sometimes for the office buildings (3.5+1)
1.75	3.00	5.25	35%	5.52	405	3.97	82.9	16.2	~assumptions often used for the office buildings (4+1)
1.50	3.00	4.5	30%	6.44	472	4.63	96.7	18.9	~assumptions used sometimes for the office buildings, close to introduced in The London Building Acts 1909 ~ 100psf
1.25	3.00	3.75	25%	7.73	567	5.56	116.1	22.7	~assumptions rarely used for the office buildings

4 Acknowledgements

We would like to warmly thank all volunteers for invaluable help in this experiment. We would like also thank the Department of Engineering University of Cambridge for the opportunity to conduct this experiment in JDB.

5 References

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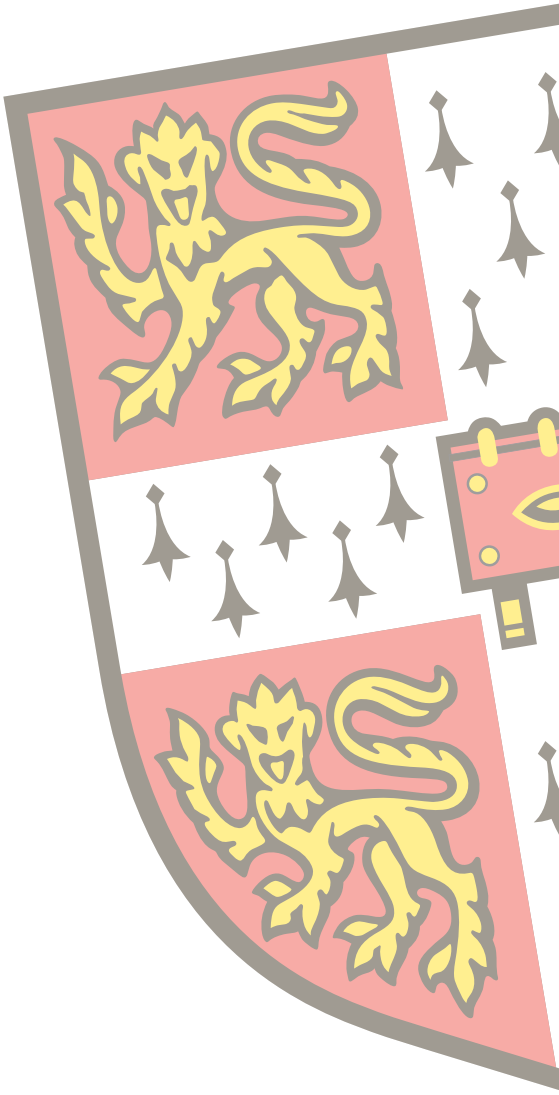

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