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LIVE LOADS SURVEY ON EDUCATIONAL BUILDINGS FLOORS

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ABSTRACT

A survey on live load has been carried out in four different private buildings in Lubumbashi, a southern town in the Democratic Republic of Congo. A total of 58 rooms covering 3325,47 m^2 were surveyed. The loads in each room were collected using methods such as direct weighing, the inventory method and weight assessment, that were previously used in similar load surveys. For each room, the sum of weights of a potentially estimated maximum number of occupants taken at once in a room was considered. The collected data were analyzed statistically. Four types of room use were identified. The results were compared to previous similar survey and to the design live load of the Eurocode 1 based on the four room types identified in the paper. The findings in this paper are paving the way for an introduction or an amendment of a design building standards adopted in this area of the world.

KEYWORDS: Design loads, Live loads, Load survey, Structural design, Structural safety, Structural engineering.

1. INTRODUCTION

The Knowledge of imposed load or live load is one of the most important components required in structural engineering in order to design and analyze structures. A significant number of research and progress have been made in the field of strength of building materials as well as its structural resistance against loading from wind and earthquake. In various countries like USA [1], Mexico [2], India [3], United Kingdom [4], live loads surveys have been performed. However, little work on live load has been carried out in Africa; except for certain countries like Ghana [5]; where few countries possess design building standards.

Keeping this in mind, it has been observed in recent years the rising of new multistory buildings in Lubumbashi, a southeastern city of the Democratic Republic of Congo. Unfortunately, due to the lack of national building regulations and standards in the country, the Congolese structural engineer is lacking guidance in the design process of structures. Therefore, the objective of this study is to carry out a survey on the live load of existing structures with a view to kick-start the development of a new National code of practice.

This paper is a survey that aims specifically to observe, to define the floor area load intensity room area load intensity and to compare the findings to other surveys and the Eurocode 1, the latter being the mainly used code in democratic republic of Congo. Throughout this paper, the detail of the survey, the methodology and the results will be presented.

2. SCOPE OF THE SURVEY

A survey on offices floors, auditoriums and library was carried in four different private buildings, Two buildings of a private High school, Age d'or 1(Figure 1) and two others buildings of New Horizons University (Figure 2). A total of 58 rooms were surveyed representing 3301,40 m2. The type of live load considered was limited to the loads resulting from the intended use of the building. This included furniture, books, papers, equipment, book shelves and others items used in the rooms. The potential maximum number of occupants taken at once in a room was also considered in the survey.

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Figure 1 : Age d'or High School

Figure 2 : New Horizons University

Due to the numerous factors influencing the results of such surveys, an attempt to reduce them was necessary and some of them were considered negligible in order to create representative sustained load parameters. Previous live-load survey findings and recommendations [1] [4] [6] were used as a base to limit the numbers of factors in order to create a reasonable size of the survey.

Culver [1] found that the height of the building, age or sector did not affect the unit floor loads. The overload intensity for all rooms and all usage, for government occupancies was closely similar to that of the private occupancies [1], [6]. In the current study, areas such as cafeteria, stairs, corridors were not considered. The weights of partition walls were excluded as these would normally be considered separately in design calculations. Besides, certain rooms were not taken into account for the live loads in them were almost inexistent.

The fluctuation of live load over time caused by the accumulation of archives, was not considered. This led to a point-in-time live load analysis as done by Kwesi [5] and Kumar [3].

3. METHODOLOGY

Data collection in similar live-load surveys were collected by using direct weighing of items, or by using inventory technique or from a manufacturer's list, and even by estimation based on experience [3].

In this survey, the direct weighing method and the inventory method fitted and were adopted to collect data. For the direct weighing of items, a 300kg weighing scale (Figure 3 and figure 4) was utilized. This method required a halt of activities in the room being surveyed, and consumed considerable amount of time. Thus, it was appropriate when the places were not solicited. The standard furniture such as tables, chairs, etc., were weighed once, the weigh information was recorded and reused to avoid repetition.

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Figure 3 : weighing process

Figure 4 : weighing scale

On the other hand, the inventory method was less time consuming, caused minimum disturbance to the occupant of the surveyed room, no equipment was required, eventually the method fitted for the period of time that requested less disruption of activities in the room. This method consisted of collecting observable physical characteristics of objects from which weight information could be obtained. Weight assessment was done by volumetric measurements [3].

For items such as piles of papers and books approximate dimensions were noted. The dimensions included the frequently used sizes of books and A4 size for papers, and their total thickness. The weights were calculated by multiplying their density by the measured volume. The volume and the weight of a sample of books were measured in order to define the average density. The various degrees of compaction of this material as based on Table 34 of Ref. [4] were not considered.

The potential maximum number of occupants taken at once in a room was also considered. The average weight of occupants was 60.7 kg based on table 3 of Ref [7] of Walpole et al.

4. STATISTICAL DATA ANALYSIS

As mentioned earlier, 58 rooms were surveyed, a total of 3325,47 m^2. The mean floor area for all the rooms was 57,34 m^2. Auditorium area occupied 65,42% of the total area surveyed, followed by classrooms (28,79%), clerical rooms (3,98%) and library (1,81%) as shown in table 1. The largest room area was found to be an auditorium

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(283,01 m^2). The mean load value of all the rooms was found to be μ=0,722 kN/m^2 and the standard deviation of σ = 0,288 kN/m^2 as the maximum and minimum load values are respectively 1,604 kN/m^2 and 0,351 kN/m^2.

Table 1 : Characteristics of floor areas

Room use	No. Of Rooms	Room area m^2.	Total area surveyed (%)	Minimum Room area m^2.	Maximum Room area m^2.	Mean Room area m^2.
Clerical	11	132,39	3,98	12,04	12,04	12,04
Auditorium	16	2175,51	65,42	55,88	283,01	135,97
Library	5	60,18	1,81	12,04	12,04	12,04
Classroom	26	957,40	28,79	29,68	53,11	36,82
All rooms	58	3325,47	100,00	12,04	283,01	57,34

This brought a variation coefficient of 40% meaning that analyzed in such manner the load kN/m^2 of rooms is widely dispersed. In order to make a more meaningful analysis, data or room were grouped and analyzed based on the room use (classrooms, auditoriums, clerical and libraries).

4.1 Statistical study of classroom loads

By observing maximum and minimum load value which are respectively 1,036 kN/m^2 and 0,593 kN/m^2, a study was done by aggregating data in classes within a range of 0.074 kN/m^2. The measures of central tendency were μ_1=0,821 kN/m^2 as mean value and M_o=0,861 kN/m^2 as mode. Given that M_o>µ_1 it is realized that the distribution has a negative skew as the skewness coefficient is near 0 (-0,347) (see probability distribution table). Furthermore, variables are lowly dispersed since the variation coefficient is 12,3 %.

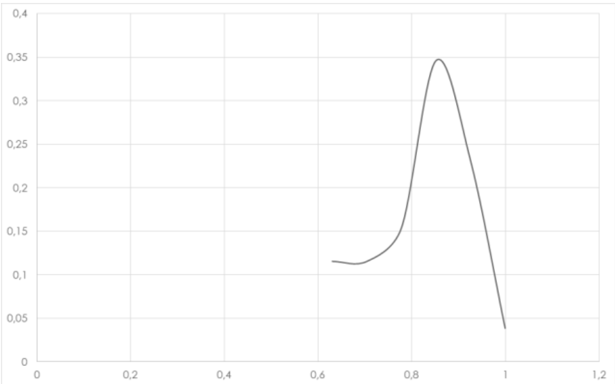

Figure 5 : Probability distribution, classrooms

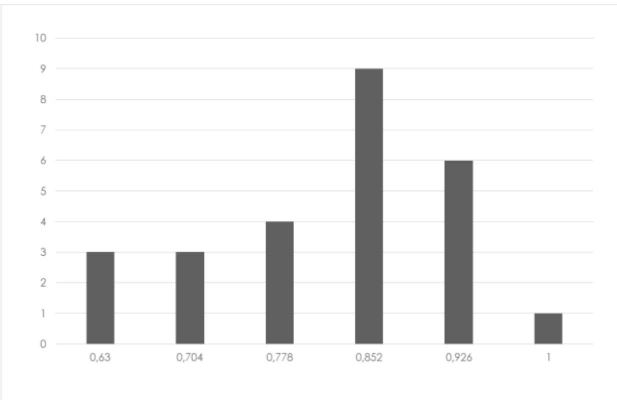

Figure 6 : live load histogram, classrooms

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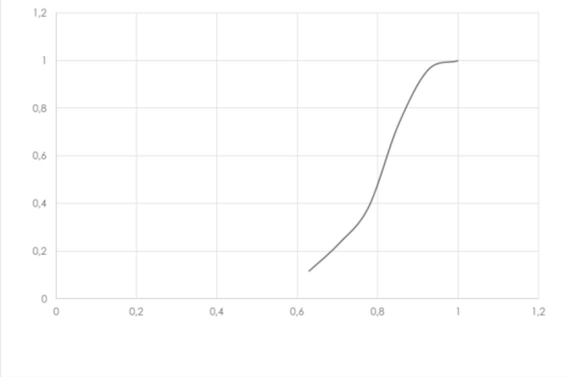

Figure 7 : Distribution function, classrooms

4.2 Statistical study of auditorium loads

As for auditorium, a similar statistical study was done. The maximum and the minimum load value which are respectively 0,758 kN/m^2 and 0,359 kN/m^2, data are aggregated in classes within a range of 0,399 kN/m^2. The measures of central tendency were μ_1=0,524 kN/m^2 as mean value and M_O=0,566 kN/m^2 as mode. Subsequently the distribution has a positive skew as the skewness coefficient is 0,4 (see probability distribution table). It was also noticed that the dataset was bimodal fig.8.

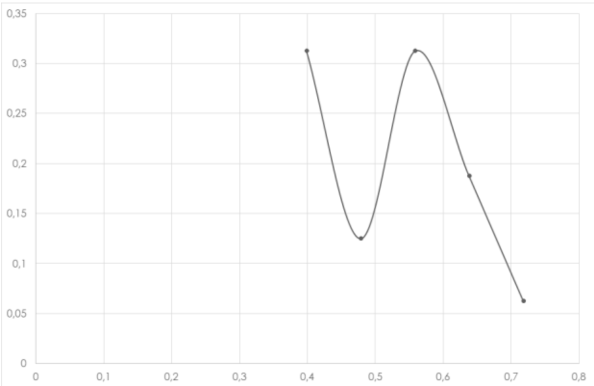

Figure 8 : Probability distribution, auditoriums

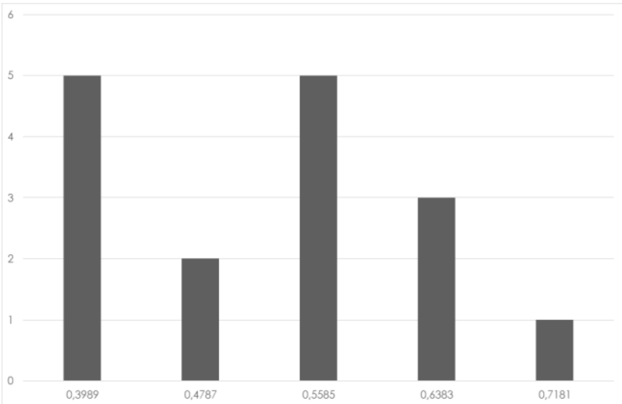

Figure 9 : live load histogram, auditoriums

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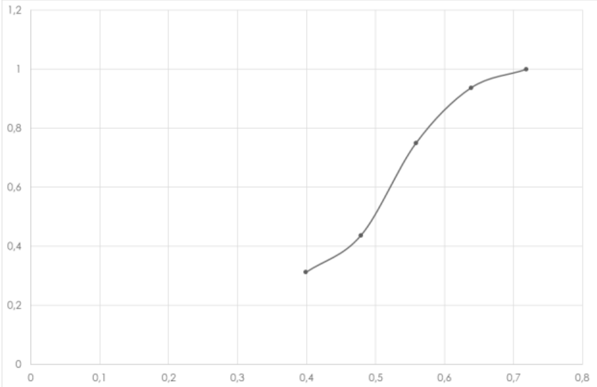

Figure 10 : Distribution function, auditoriums

4.3 Statistical study of clerical room loads

Given that the numbers of clerical rooms are not substantial, a total of eleven, the data were manipulated as discrete. The value for the mean, the mode and the deviation standard were respectively 0,423 kN/m^2; 0,351 kN/m^2 and 0,057 kN/m^2. Subsequently the coefficient variation is 13%.

4.4 Statistical study of library rooms loads

A total of 5 rooms has been surveyed for the library. As for the previous section the data were discrete. The value for the mean and the deviation standard were respectively 1,479 kN/m^2, 0,111 kN/m^2 whence a very low coefficient variation meaning that all the 5 rooms are almost identical.

5. RESULT AND DISCUSSION

Four types of room use identified in the survey were classified into three categories of use according to table 6.1 and table 6.3 of Eurocode 1 [8] . Clerical rooms were categorized as B, Auditoriums and classrooms as C1 and Library as E1. Table summarize the result of the comparison of the present project with the Eurocode (EC1) in terms of live load. The mean load values found in the survey were 85,90%; 72,63%; 82,53% and 80% lower than the normative or design live load recommended in the table 6.1 and 6.3 of [8], respectively for clerical, classrooms, Auditoriums and library. Design loads proposed by EC1 are far in excess of the design loads estimated from the survey data.

Table 2 : Comparison to EC1

Category EC1	Room use	Mean load (kN/m^2)	Normative Load (kN/m^2)
B	Clerical	0,423	3
C1	Classrooms	0,821	3
	Auditoriums	0,524	3
E	Libraries	1,479	7,5

The results of the present survey were compared with two other surveys [3, 5] in India and Ghana. The variation between the live-load survey results of the two surveys on one hand and the present work on the other are direct. This variation is likely due to a number of reasons viz, social environment, cultural background, difference in applied methodology, time interval between different surveys and the difference in scope of surveys. The Ghana and India survey were conducted respectively four and two decades ago.

Tables 3 and 4 summarize the results of the comparison of present survey with those of the two surveys.

From table 3 it is observed that the present survey covers 28,37 percent and 11,95 percent of the total area surveyed of the two previous works, respectively Kwesi [5] and Sunil [3]. The number of rooms surveyed of the present

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paper is far lower than the previous. Kwesi [5] present the highest average live load 2,056 kN/m^2 followed by the present paper 1,479 kN/m^2 and finally Sunil [3] 0,743 kN/m^2. The present survey has the highest mean live load 0,722 kN/m^2. This might be due to small size of the survey.

Table 3 : Overall comparison to Ghanaian and Indian surveys

Survey	Total area surveyed (m^2)	No of Rooms surveyed	Highest average live load (kN/m^2)	Minimum average live load(kN/m^2)	Mean live load(kN/m^2)
Sunil Kumar ,India (2000)	27818	1353	0,743	0,112	0,334
KWESI A. ANDAM, Ghana (1985)	11719,8	388	2,056	0,062	0,458
Present work, DR Congo (2021)	3325,47	58	1,479	0,365	0,722

Table 4 indicates that the mean live load of the library is the highest for the surveys. The present paper has the highest value. This is due to the small size of rooms used for library. As it has been observed from previous surveyed that loading intensity increase with a decrease in room floor area [3].

Table 4 : Mean live load comparison according to room use

Survey	Total area surveyed (m^2)	No of Rooms surveyed	Highest average live load (kN/m^2)	Minimum average live load(kN/m^2)	Mean live load(kN/m^2)
Sunil Kumar ,India (2000)	27818	1353	0,743	0,112	0,334
KWESI A. ANDAM, Ghana (1985)	11719,8	388	2,056	0,062	0,458
Present work, DR Congo (2021)	3325,47	58	1,479	0,365	0,722

Although there are differences between the survey results of the present work and those of the surveys carried out in the Ghana and India, the overall characteristics and trends of variation of live loads are observed to be similar.

6. CONCLUSION

A survey on live loads has been carried out in four buildings in Lubumbashi, Democratic Republic of the Congo. After the consideration of the effects of several factors on the live loads and based on the survey results of the buildings presented in this paper, the following conclusions can be drawn.

- The overall mean live load for all the rooms was 0,722 kN/m^2. The standard deviation of live load was 0,288 kN/m^2. In a statistical study, rooms must be categorized according to their use to reduce the coefficient deviation.
- The highest mean live load value in the survey is found to be of the library 1,479 kN/m^2 followed by classrooms 0,821 kN/m^2, then auditorium 0,524kN/m^2 and finally the clerical room 0,423 kN/m^2.
- The mean load values found in the present paper are far lower than the normative or design live load recommended in the table 6.1 and 6.3 of the Eurocode 1 [8].
- Compared to two previous surveys [3] [5] in India and Ghana, this paper presents a small-scale survey. The overall mean live load in this paper was the highest.

Despite the differences between the survey results of the present work and those of the surveys carried out in the Ghana and India, the overall characteristics and tendency of variation of live loads are observed to be similar.

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It will be recommended to have more studies by surveying more buildings in Democratic Republic of the Congo in order to have more data to analyze, thus allowing the possibility to set a local value of design load. It is noteworthy that there is a high probability that we find out, after further more elaborated studies on a larger scale, that the European standards currently used, present live loads too high for the local stress conditions in the Democratic Republic of the Congo.

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