SUMMARY AND CONCLUSIONS

10.1 SUMMARY

This load survey of existing occupancy loadings in modern office buildings was intended to provide necessary information to be used with probability based modern structural design methods and to estimate the potential severity of fire in such buildings. The survey covered five office buildings covering a total floor area of about 28 500 m^2 in 459 rooms to estimate the imposed and fire loads. Procedures and techniques were developed to economically and efficiently collect and process the data.

The survey included actual weighing of all load items found in the building using simple weighing equipment. Detailed floor plans were prepared showing the positions of various loads on the floor for further take off in the data analysis. A separate survey was conducted to find out the weight of office personnel.

A finite element technique was developed to evaluate the EUDLs for various structural effects in floor slabs. The computational steps involved in the above technique are illustrated in FIG.6.4. In addition to the effects in bay slab, the structural effects in supporting beams and columns of the bay were also studied by a separate analysis. The percentage reduction of loads for beam and column design was also determined by a direct analysis of beams with loads from their contributory areas.

Along with the estimation of imposed loads, an attempt has been made to make some fire studies on buildings. The data collected in the survey formed a single source of information for both imposed and fire load studies. From the survey data, the fire load density and fire severity in office buildings were also evaluated.

The data analysis yielded the frequency distributions and their statistical parameters for the following:

i) Imposed room load intensity
ii) Imposed bay load intensity
iii) Equivalent uniformly distributed imposed loads
iv) Effective imposed loads on beams
v) Effective imposed loads on columns
vi) Fire load density
vii) Fire severity.

The various mathematical probability distributions were fitted to the above various observed data to find out a best fit to represent the actual distributions from which the upper fractiles which are of design interest can be obtained. Using appropriate stochastic mathematical model that are already available, the life time maximum loads could be obtained for which additional information on such other factors like duration of occupancy, transient loads etc. are needed.

10.2 CONCLUSIONS

Based on the survey results presented herein, the following conclusions were drawn:

1. Even though the present survey is the fourth largest survey, conducted so far in the world (in terms of area covered) (TAB.5.2) it is the first of its kind in India. To the best of author's knowledge it is the most extensive evaluation of EUDL with more realistic conditions.
2. The SAPINPUT and MAXPICK programs developed by the author along with any suitable Finite Element Method of Structural Analysis would be the useful method of analysis for evaluation of EUDLs based on structural effects in bay slabs under actual loading conditions.
3. The room load intensity and fire load density are related to the room use. The store rooms were the most heavily loaded. In general, the room load intensity decreases with increase in room area although room use and room area are correlated. The mean load intensity in large rooms ($> 30\ m^2$) is only about 60% of the load intensities in small rooms ($\leq 10\ m^2$). More data with room areas larger than $40\ m^2$ are needed to delineate a more specific relationship between room use and room area.

   The mean room load intensity was about 30% more than bay load intensity.
4. The sizes of structural bays in office buildings are governed by the optimal design consideration like column spacing and frame spacing and hence are not likely to vary to a great extent. This was also confirmed in the studies conducted by the author. Hence there is not much likelyhood of bay load intensities varying as a function of bay size.

5. About one-third of the floor area in office buildings was occupied by furniture and other items. Usagewise, the mean occupied area was 27% in officers' rooms, 33% in general office area and 37% in store rooms.
6. The variation of loads between the floors is not significant, but the variation within the floor for different rooms is significant due to room usage.
7. There is a marked difference between the EUDL which is based on structural effects in the supporting structure and the usual Room or Bay Load Intensities which are only nominal load intensities. The mean load concentration factor (Ratio of mean EUDL to mean BLI) is as high as 2.0.
8. Only about 10% of Bay EUDLs are governed by either beam or column effects in a bay and therefore difference between 'slab EUDL' and 'bay EUDL' was found insignificant. Hence the analysis of effects on beams and columns in individual bays may be dispensed with in future analysis.
9. The load effects due to span moment and shear together, were more predominent over the other stress resultants in more than 90% of bays and hence only these two effects need to be considered in future analysis of bays.

In one way reinforced slabs span moment is more predominent whereas shear is predominent in two way reinforced slabs.

10. For the beam and column designs, the basic loads used in the design of slabs can be reduced by about 40% even while considering the loads on a single floor.
11. The movable fire load in offices constitutes around 80% whereas the fire load due to enclosed content and interior finish are around 5% and 15% respectively.
12. In general, the lognormal distribution is found to be the most appropriate choice for describing the various loads and also fire severity.
13. The statistical parameters and the upper fractiles of various loads and fire severity are as given in TAB.10.1.
14. The observed 95% probable EUDL of 2.35 kN/m^2 in office buildings without separate store rooms is very much less than the present I.S. Code provision of 4.0 kN/m^2 for the design of such buildings which seems to be close to the 99.6% probable level.
15. At the suggested significance level of 5% the probable fire severity was 85.6 minutes, which suggests that the 'Grade-3' or superior types of construction are suitable for office buildings from the safety point of view.

10.3 SUGGESTIONS FOR FUTURE WORK

Several suggestions are given hereunder for further studies on imposed loads and fire loads.

1. Continuous monitoring of loads in buildings is required to establish the actual time-dependent characteristics of the imposed loads if financial limitations permit.

TABLE 10.1: Distribution Characteristics

Characteristics	RLI (kN/m^2)		BLI (kN/m^2)	Slab EUDL (kN/m^2)	Beam Load (kN/m^2)	Column Load (kN/m^2)	Fire Load Density (kN/m^2)	Fire Severity (min.)
	With SR*	Without SR						
No. of observations	(459)	(428)	(736)	(736)	(1615)	(1360)	(459)	(459)
Maximum value	4.50	1.67	2.12	5.11	4.67	3.15	3.42	576.3
Minimum value	0.12	0.12	0.08	0.17	0.02	0.02	0.05	4.4
Mean value	0.75	0.68	0.54	1.08	0.66	0.58	0.36	33.7
Standard deviation	0.46	0.30	0.27	0.61	0.41	0.33	0.36	43.4
Coefficient of variation %	61.2	43.5	49.2	56.6	62.2	56.5	98.2	129.0
Skewness coefficient	3.2	0.7	1.7	1.9	2.3	2.1	3.7	6.5
95% Fractile	1.45	1.27	1.03	2.35	1.43	1.15	0.86	85.6

*SR - Store rooms

2. Survey should be repeated after occupancy changes in order to determine whether the respective loads are consistent with the same parent population, and to determine the correlation that may exist between the localised loads due to each of the occupancies.
3. To collect load data on the above is to repeat surveys in buildings that have previously been surveyed. This will only be of value if the original survey results as to the load intensities in each room/bay, and EUDL of each bay and the corresponding load effect are available.
4. Information regarding the clustering of personnel on special occasions are to be obtained for evaluating the transient loads by questioning the occupants or by referring to the records of attendance if available which is of course not a reliable method.
5. For realistic representation of design loads in codes of practice only EUDLs should be evaluated, but not the room load intensities which are only nominal loads.
6. Detailed floor plans are to be made in a load survey for exact location of loads which influences the EUDL.
7. To reduce the quantum of office work involved in surveys and to speed up the data analysis without substantially affecting the accuracy of results, the following simplifications are suggested in the analysis of bays:

i) Conduct only slab analysis and dispense with analyses of supporting beams and columns for individual bays.

ii) Even in slab analysis, consider only the effects of span moment and shear.

8. Besides the evaluation of imposed loads on buildings, evaluation of construction loads (due to stacking of building materials, use of construction equipment, due to floor to floor propping) which are sometimes feared to be more dangerous especially with human safety are to be given importance.

9. More functional groups of offices are to be covered to make the results more representative.

10. Additional surveys are to be conducted in more buildings to consolidated the findings.

11. The report of each survey should carefully explain the procedure of survey, list the loads included and those excluded and assumptions concerning the personnel loading.

12. Load surveys are to be conducted in other occupancies too with the developed methodology and techniques of the present survey.

13. Since construction practices evolve over the years and the nature of building contents change, repeat the fire load surveys to update the data to reflect their conditions.

14. To know the influence of extraordinary loads due to stacking of room contents at one place in a room, simulation studies can be made with the existing data by randomly changing the location of the loads within a structural bay.
15. The reduction of column loads involving multifloors may be studied in buildings where floor plans coincide with each other.