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Free Discussion / Discussion libre / Freie Diskussion

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I should like to make several random comments on loadings based on recent research and experience.

1. Load Studies; Load studies are expensive and no little care should be taken to avoid collecting more information than is needed. It is important to remember that the interest is not in the data for its own sake, but for eventual use in guiding structural design. This simple observation has led to several data collection implications. For example,

a. If one is satisfied with estimating the member forces in supporting beams and columns it appears to be satisfactory to obtain rather gross information about the spatial disposition of the loads. Analysis suggests that the U.S. National Bureau of Standards scheme of recording the load location as simply being in one of nine sections within a room introduces negligible uncertainty in the member force prediction.

b. The load data uses seem to dictate a need for either extreme load data or simple means and variances, but not for complete descriptions.

i) For design of slabs and members sensitive to "local" loads, data from the upper tail of the load probability distribution is needed. This can probably be obtained most cheaply by training crews to sample "conditionally," e.g., with orders to measure only rooms which they estimate by quick visual check to have loads in excess of x pounds per square foot.

ii) For design of members with respect to non-failure limit states (e.g., deformation, cracking, etc.) and for members, such as major columns and footings, which support the sum of many room or bay loads, it appears to be satisfactory to estimate only the mean and variance. Sufficiently accurate estimates can be obtained with only ten to twenty rooms per building (or perhaps per firm.) Obtaining estimates of the building-to-building variation is very important, if, as some suspect, this variation is significant compared to within-building variation. The reason will be demonstrated below.

c. The degree of spatial correlation among loads in a building is important in major members, such as columns, which support many individual loads. If a column supports two floor loads (with common variance σ^2) the variance of the column load is $2\sigma^2(1+\rho)$, in which ρ is the correlation coefficient between the loads. Since ρ is probably positive in this case, the estimate of the column variance can be underestimated by a factor as large as 2 if the common simplification of independence ($\rho = 0$) is adopted.

d. A primary source of this spatial correlation can be among or building-to-building variation. A discussion by R.B. Corotis and me (in the July 1969 Journal of the Structural Division of ASCE) shows that, even if there is no within-building spatial correlation, the correlation coefficient between the two floor loads is $\rho = \sigma_A^2/(\sigma_A^2 + \sigma_w^2)$ = (among)/(among + within). Clearly this number will be significantly larger if among-building variation is large compared to within-building variation. This conclusion supports the need for adequate sampling of many different buildings, not simply careful sampling within buildings.

e. As others have mentioned these loads, being measured as they are, at effectively random points in time, do not represent observations of the maximum peak loads during a building's lifetime. Mr. Mitchell's suggestion of treating occupancy changes as being randomly selected from the (spatially measured) population seems quite reasonable. For smaller members, at least, some consideration must be given also to loads due to concentrations of people. The N.B.S. is recording open, unloaded area as a simple measure of the potential for loads due to people. Rooms heavily loaded with static loads can be expected to have less potential for loads due to people, i.e., a negative correlation can be expected between static load and unloaded area (or "people-load potential").

2. Load Combinations; The problem of properly combining loads in probabilisticly based codes has been referred to here several times. It is important to keep in mind in this regard that loads (or load effects) are in fact random functions of time. A variety of random variables associated with such random functions are important. When designing for peak gravity loads, the designer should be interested in the mean, variance, characteristic value, etc., of the random variable: peak live load during the structural lifetime. Design for wind combined with live load is another problem, however. As many have observed, it is unlikely that the peak lifetime wind load will occur simultaneously with the peak live load. Comparing the rapid versus slow fluctuation of the two random time functions and assuming that they are effectively uncorrelated functions, it would appear to be reasonable and practical to treat this combined loading by adding to the peak wind load random variable, the instantaneous (i.e., arbitrary point in time) live load random variable. This is, of course, precisely the variable which is being observed in the present load surveys.

3. Earthquake Risks; To support a previous discussion that illustrated that probabilistic methods are to be used in design, I can cite recent experience in using probabilistic methods (Cornell, B. Seis. Soc. Amer., V. 54, No. 5) to estimate the probability of exceeding design earthquake intensity values for nuclear power plants. Interestingly enough, when several different sites were analyzed in this manner and the probabilities calculated for

each of the two rather arbitrarily defined design levels ("maximum probable" and "maximum credible"), both of which had been previously, independently selected by rather arbitrary means, a surprising degree of consistency was found. The former level usually corresponded to a return period of about 10^3 years and the second to 10^5 or 10^6 years.

III

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I would like to add the following comments to Mr. Newberry's fine paper:

1. I wholeheartedly agree with Mr. Newberry's plea that wind-load requirements should not be lowered until more research in this area has been completed. In the past, buildings have been far stronger in resisting wind pressures than those for which they were designed; primarily, on account of the existence of non-load bearing partitions. However, the tendency today, at least in the United States, is for office buildings to be built with moveable partitions. Many partitions that are not moveable do not extend all the way from floor to ceiling. Therefore, we no longer are guaranteed the built-in added safety factor so frequently present in the past.

2. In ACI Committee 348 (Structural Safety), we consider serviceability to be one aspect of structural safety. Therefore, it is not enough to design a building to withstand wind pressure so that the building will not collapse. The building must also be comfortable for those inside it. This gets to be important as more of our tall buildings are apartment buildings, not only office buildings as in the past. Wind deflections which might be acceptable to workers in an office building, may be totally unacceptable to tenants living in an apartment building.

Concerning Mr. Mitchell's paper, I would like to add the following comments:

1. There is usually very little control of construction loads by the designing engineer and sometimes not even by the contractor. This is a problem which engineers should consider during their design and contractors in planning their construction sequence. Many more buildings collapse during construction than after they are completed. This is especially true of concrete buildings where frequently construction loads far in excess of the design live load are imposed on parts of the structure which have not yet attained their design strength and are not intended to for twenty-eight days.

2. For snow loads, the duration of the load must be considered together with the intensity of the load.

3. In addition to those mentioned there are two other load surveys being conducted in the United States; one by the Post Office Department of its facilities and the other by the National Bureau of Standards, the latter being confined to office buildings.