OFFICE OF THE ILLINOIS STATE FIRE MARSHAL

Calculating Occupant Loads in Assembly Occupancies

Using NFPA 101, *Life Safety Code* (2015 edition)

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Calculating the Occupant Load in an Assembly Occupancy Using NFPA 101, *Life Safety Code* (2015)

The Office of the Illinois State Fire Marshal (OSFM) has adopted the 2015 edition of NFPA 101, *Life Safety Code* (referred to in this document as the "LSC") as the statewide standard for fire prevention and life safety. NFPA 101 is published by the National Fire Protection Association. The LSC is a comprehensive code that addresses many issues relevant to fire and life safety in new and existing occupancies, such as fire alarm and fire suppression systems, exit lighting, emergency lighting, number of exits, width of exits, and the type of interior finish that is allowed in the building.

The LSC applies different requirements for different types of occupancies. For example, an assembly occupancy would be required to meet different requirements than an education occupancy, business office, hotel, or a storage occupancy. This document limits its discussion to the review of the LSC's methods for determining occupant loads and necessary exit capacity of an assembly occupancy. This document does not discuss the method of calculation for other occupancy classifications. It should be noted that other occupancies will follow the same procedures as described in this document, but use different occupant load factors or capacity factors. Therefore, the associated math is different for other occupancy classifications, as are the resulting conclusions.

An important consideration in these life safety calculations is the movement and behavior of people in emergency and non-emergency scenarios, which has been researched for decades. The results of this research is established as prescriptive requirements in the LSC. The class of occupancy that depends heavily on this research is the Assembly Occupancies (Chapters 12 and 13 in the LSC). The assembly chapter requirements deal with the movement of very large numbers of people—people who sometime could be under the influence of drugs or alcohol. These same people have to ascend or descend stairs, moving along with a crowd of other people who may also be unfamiliar with the assembly and/or influenced drugs or alcohol, all while trying to make their way out of an unfamiliar building.

Determining occupancy load requires three main focuses (highlighted below)that are further broken down into seven steps. It should be noted that the preliminary occupant load could be reduced by other parameters identified by the number of means of egress requirements, egress capacity requirements, and main entrance/exit requirements.

Calculate The Preliminary Occupant Load

1. Determine proper occupant load factor to be used.
2. Determine if the occupant load factor incorporates "net" or "gross" floor area.
3. Calculate the preliminary occupant load.

Determine the Minimum Number of Means of Egress, Based on Occupant Load

4. Determine the minimum number of means of egress, based on occupant load

Determine the Egress Capacity Based on the Calculated Occupant Load

5. Determine egress capacity needed for the calculated occupant load.

6. Determine minimum width requirements for aisles and aisle accessways located within seating arrangement.
7. Determine main entrance/exit requirements.

STEP 1: DETERMINE PROPER OCCUPANT LOAD FACTOR TO BE USED

The LSC defines what is called an "occupant load factor" for the use of a building or of a space within a building. Occupant load factors are prescribed in Table 7.3.1.2 of the LSC and are based upon the use of the building or space being calculated, and not the overall occupancy classification of the building.

For example, when applying the requirements of the LSC for a meeting room located within a business occupancy, the “occupant load factor” from Table 7.3.1.2 for the actual use of the room must be taken into consideration, and the factors associated with an “assembly use” would be applied to the meeting room. It is that “assembly use occupant load factor” that determines whether the occupancy load of the meeting room is classified as either “business use” (fewer than 50 occupants) or “assembly use” (50 or more people). If the occupant load calculation results in a value of 50 or more, then the classification of that meeting room would be “assembly use,” and the assembly chapters from the LSC would be used in the life safety design for that meeting room. On the other hand, if the calculations yielded a value of less than 50, then the classification of the room would be “business use.”

The “occupant load factor” is a number that describes how many square feet per person (ft^2/person) should be provided when determining the preliminary occupant load. For example, in an assembly occupancy, the two most commonly used occupant load factors are 7 ft^2/person (net) and 15 ft^2/person (net).

- The 7 ft^2/person factor is used for “concentrated use” assembly occupancies, such as the nightclubs, dance floors, or multipurpose rooms where portable chairs are placed in rows for meetings, film viewing, lectures, or other similar seating arrangements.
- The 15 ft^2/person factor would be used in “less concentrated use” assembly occupancies that do not have fixed seating, and where a certain amount of space is occupied by furniture, such as seating at dining tables or in a meeting room that uses conference tables.

In assembly occupancies with fixed seating, however, the occupant load is simply the number of fixed seats, although the calculations must also take into account the available egress capacity and minimum widths of aisle and aisle accessways. All of this is discussed in more detail later in this document.

Also be aware that occupant load factors for specialty use areas such as bench-type seating, assembly kitchen areas, swimming pool decks, exercise equipment rooms, stages, casino gaming areas, and skating rinks are addressed separately in Table 7.3.1.2 in the LSC.

STEP 2: DETERMINE “NET” OR “GROSS” FLOOR AREA

Once the occupant load factor is determined, the area of a space or building must be determined, which is normally measured in square feet (ft^2). It is also important to note that some occupancies in Table 7.3.1.2 allow the "net" area of a space or building to be used in conducting these calculations, while other occupancy classifications must use the “gross” area of the building when determining occupant loads.

When the LSC designates that "net" area can be applied, this means permanent objects that take up space where people cannot sit or stand are subtracted from the total area of the room or building. For example, space taken up by a bar, pool tables, storage rooms, washrooms, or structural members such as columns would be subtracted from the total area because people cannot stand in or occupy these places. In Table 7.3.1.2, all factors are expressed in "gross" area unless the factor is marked as "net."

STEP 3: CALCULATE THE PRELIMINARY OCCUPANT LOAD

Once the total area of the building or space in question is known (using the prescribed "gross" or "net" areas as addressed above), then this area is divided by the previously identified occupant load factor to obtain a preliminary occupant load.

For example, if the area of an assembly building that is used as a night club is measured to be 11,000 ft^2, the non-occupiable spaces must be subtracted from the 11,000 ft^2 because the occupant load factor for concentrated assembly use is identified in Table 7.3.1.2 as "net" area. It was determined that 1,000 ft^2 of space is not occupiable. Hence, the "net" occupiable area is calculated as 10,000 ft^2 (11,000 ft^2-1,000 ft^2=10,000 ft^2). From Table 7.3.1.2 of the LSC, the occupant load factor for concentrated assembly use is 7 ft^2/person. The preliminary occupant load would be:

10,000 ft^2 ÷ 7 ft^2/ person	= 1,428 occupants. This is the preliminary occupant load.

STEP 4: DETERMINE THE MINIMUM NUMBER OF "MEANS OF EGRESS" BASED ON OCCUPANT LOAD

Most buildings are required to have a minimum of two means of egress, located remotely from each other. Therefore, even though the calculated egress capacity necessary for exits could be achieved with the installation of a single door, there are independent requirements related to the number of means of egress. The minimum number of means of egress becomes even more critical in occupancies with large occupancy loads, such as assembly occupancies.

- Section 7.4 of the LSC requires that if 50–500 people occupy the building or space, then at least two exits are needed.
- For a new building, if 501–1000 occupants are calculated, then a minimum of three exits are needed, although Section 13.2.4.2 for Existing Assembly Occupancies permits an occupant load of up 600 before triggering a third means of egress for an existing building
- Lastly, if more than 1000 occupants are calculated, then a minimum of four exits are required to be provided.

As discussed, earlier, other parameters may trigger additional means of egress, beyond what Section 7.4 calls for. The minimum means of egress "capacity" requirements would require many more means of egress for a large arena where tens of thousands of occupants are in attendance. Minimum egress capacity is addressed further in following discussions.

STEP 5: DETERMINE EGRESS CAPACITY NEEDED FOR CALCULATED OCCUPANT LOAD

Once this preliminary occupant load is known, the LSC prescribes a method of calculating egress capacity, or just how wide the means of egress components (aisles, aisle accessways, corridors, ramps, doors, and stairs) need to be to safely egress the calculated preliminary occupant load from the building. Think of water flowing through a fire hose or cars traveling an interstate highway. In the fire hose analogy, a hose flowing 1,000 gallons per minute must be larger than hose flowing 200 gallons per minute.

For cars to "flow" at the speed limit on the Kennedy Expressway in Chicago during morning rush hour, the expressway would need to be substantially wider to handle the much larger number of rush hour vehicles than during lower flow periods of the day. This also applies to moving people through buildings. In fact, the people movement formulas are very similar to the vehicle movement formulas when designing means of egress/traffic flow capacity.

For people movement, this involves the use of a "capacity factor" prescribed in LSC Table 7.3.3.1. For all assembly occupancies, the capacity factor for level components found in a means of egress (doorways and ramps, but not stairs) is 0.2 inches/person (in./person), while the capacity factor for stairways is 0.3 in./person. The capacity factor is multiplied by the total number of occupants to determine how many inches of width must be provided for the occupants to safely egress from the space or building. The following illustrates the differences between egress on a level plane as opposed to egress going down stairs:

- If the occupants are traveling out of a building on the same level (in other words, using doors or ramps and not negotiating stairs to get out), then the LSC prescribes taking the occupant load and multiplying it by 0.2. In the example found in Step 3, where calculations arrived at a preliminary occupant load of 1,468 persons, this would mean:

1,428 persons x 0.2 in./person=285.7 inches of level component width

- The number above is the number of inches of width that must be provided for the building to safely move 1,428 occupants through and out of the building. The building, for example, could provide 8 doors that are each 36 in. in clear width to provide a total of 8 x 36 in.=288 inches of exiting width to comply with the requirement.
- If the occupants need to travel down stairs to exit, on the other hand, then the LSC-prescribed factor of 0.3 in./person must be used to calculate the exit width. Again, for the above example this would mean:

1,428 x 0.3 in./person=428.4 inches of stairway width.

Note that the total required egress width of stairs is larger than the total egress width resulting from calculating level paths of egress such as doors (428 in. for stairs compared to 285 in. for level components). More stair width is required than what may be provided. Therefore, the stairs are acting as a potential pinch point for this means of egress, and the occupant load would have to be reduced come into compliance with the existing stair capacity requirements.

Why are the capacity requirements more stringent for stairs, than for level components? The LSC recognizes that the biomechanics of walking down stairs causes side-to-side swaying which prevents people from walking shoulder to shoulder as they would on a level plane, and therefore additional egress width is needed when stairs are part of the egress path. Also contributing to the wider stair requirements is the fact that people are generally going to be moving more slowly down stairs than when they are moving on a level floor.

Finally, it is important to note that when calculating capacity widths in a building, the entire length of travel from the assembly area to the exterior public way must be evaluated to confirm the required capacity widths are being maintained for that entirety.

STEP 6: DETERMINE MINIMUM WIDTH REQUIREMENTS FOR AISLES AND AISLE ACCESSWAYS LOCATED WITHIN A SEATING ARRANGEMENT

The LSC requires that minimum widths be provided for both seating aisles and seating aisle accessways. These minimum widths could very well be criteria that limit the occupancy load of a space. The user should reference Section 12.2.5 for new assembly occupancies or 13.2.5 for existing assembly occupancies in the LSC for the requirements. Whether seating is fixed seating or non-fixed seating, the aisle accessway is the initial portion of an exit access that leads to an aisle. Normally, it is the walking area situated between rows of seats or seating at tables. The aisle is the part of exit access travel that leads from the aisle accessway to the doors leaving the assembly area.

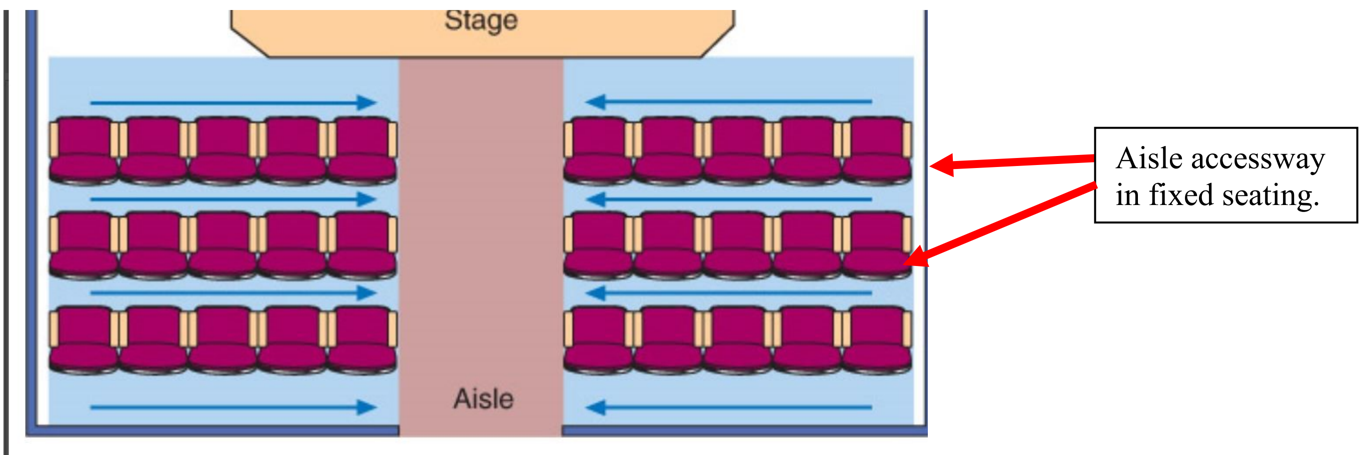

Exhibit 12/13.44
Aisle accessways.

STEP 7: DETERMINE MAIN ENTRANCE/EXIT REQUIREMENTS

The LSC recognizes an important characteristic about the occupants of assembly occupancies. Most occupants tend to exit a building via the door or stairway which they used to enter the building. This is what the industry calls the “main entrance/exit.” Main entrance/exit requirements apply not only to the building that houses an assembly occupancy, but to single assembly areas within a building. For example, a gaming casino may have several gaming areas. Each gaming area must comply with main entrance/exit requirements. Additionally the casino as a whole must comply with main entrance/exit requirements.

The LSC requires that no matter how many different exit paths are provided, the main entrance/exit must be able to handle 50% of the calculated occupant load. The remaining exits provided must be able to handle the remaining 50% of the required egress capacity. In certain occupancies such as night clubs, dance halls, discotheques, and assembly occupancies with festival seating, the main entrance/exit must be able to handle 66% of the calculated occupant load.

PUTTING IT ALL TOGETHER

Steps 4, 5, 6, and 7 are what will revise the preliminary occupant load which is calculated using Steps 1, 2, and 3. The egress capacity may not be able to handle the number of occupants calculated in the preliminary occupant load—for example, stairs may act as pinch points as seen in the capacity example shown above.

Possibly a large assembly area located within a building has the proper number of exits and proper capacity, but occupants are discharged into the main building within which the assembly occupancy resides, but the means of egress from that main building may be found to be insufficient for the assembly use. Another challenge may be found with a main entrance/exit that is not designed for a capacity of 50% or 66%, depending on use. For existing buildings, the preliminary occupancy load would have to be reduced based on all the parameters—number of means of egress, capacity of means of egress, and main entrance/exit capacity—provided that the authority having jurisdiction is confident in their ability to enforce this reduced occupancy load. For a new building, any corrections will need to be made to the building itself to comply with the results of the occupant load/means of egress evaluation.

OTHER CONSIDERATIONS AND REQUIREMENTS

The calculated occupant load using this process DOES NOT establish an absolute maximum number of occupants that can be in an assembly occupancy. This point is often misunderstood by code officials and building owners. The purpose of this process is to establish the minimum egress requirements, or a starting point that must be provided to ensure safe egress for the calculated number of occupants. Occupancies that provide more than the prescribed number of exits (and thus greater means of egress capacity) may have additional occupants in the room or space as a result of that greater capacity.

There is, however, a point when no matter how many exit doors or inches of exit width are provided, occupants can simply be too packed into an area to allow for efficient exiting. The LSC defines this as the "jam point." When the number of people in a crowd reach the jam point, response of the occupants starts to change because of constant contact between people. That in turn can sometimes lead to pushing, resistance, and panic as people's behavior becomes increasingly agitated. When the following occupant load densities are reached, then no more occupants are permitted in an assembly:

- Not less than 3 ft^2/person in waiting spaces,
- Not less than 5 ft^2/person in occupancies with areas of less than 10,000 ft^2, and
- Not less than 7 ft^2/person in occupancies with areas in excess of 10,000 ft^2.

Also, it is important to note that even if a building or room is provided with a sufficient number and width of egress routes to comply with the above calculation methods, other requirements of the LSC associated with the means of egress may still cause the building to be in noncompliance with the requirements found in the LSC. For example:

- Exits must be marked with code-complying exit signs.
- Exits must be clear and unobstructed.
- Interior finish material (the material affixed to walls, floors and ceilings) must comply with code requirements for flame spread and smoke developed ratings.
- Prescribed travel distances to reach the closest exit from any point in the occupancy must be met regardless of the total number of exits provided to the occupants.
- Doors serving more than 50 occupants must swing in the direction of exit travel.
- Doors serving more than 100 occupants and capable of locking or latching must have approved panic or fire exit hardware.

As you can see, calculating the occupant load in an assembly occupancy is complex and many-faceted. We hope this information sheet helps to clear up any confusion and point you in the right direction. As always, feel free to contact OSFM's Technical Services Unit if you have additional questions or concerns.

For additional information, please review the NFPA Fact Sheet Calculating Occupant Load

The best way to contact Technical Services is by email at SFM.Techservices@illinois.gov.