Structural Practices

practical knowledge beyond the textbook

Elevators for Tall Buildings

By Jack Tornquist

Elevators in high-rise buildings are a necessity. They move people without noticeable waits, transport staff and materials, complement the building design, and enhance the building's market reputation. Elevators must operate safely and seamlessly.

When buildings are designed, architects enlist the assistance of elevator specialists to determine the proper number, grouping and type of elevators. This approach ensures adequate capacity and provides appropriate waiting times without providing too many elevators. High-rise buildings, those with more than 20 floors above the lobby, can have multiple elevator groups, low-rise, mid-rise and high-rise for example, and sometimes parking, retail and special use elevators, along with service and material elevators.

In most high-rise structures, elevator cabs are suspended from steel cables which are moved by a hoist machine, which then propels the elevator cab. This article addresses structural designs to accommodate traction elevators (*Figure 1*). These elevators can have capacities ranging from 2,500 to 20,000 pounds or more, and travel at speeds ranging from 200 feet per minute (fpm) to more than 2000 fpm.

Key elevator design criteria for the elevator system, and the related building structure are detailed and defined in the *Elevator and Escalator Safety Code*, ASME A17.1. This code is updated annually and a new version is issued every 3 years by the Code Committee. Local jurisdictions often are tentative in adopting newest codes, wanting to become familiar with the updates and changes before adoption by local law or statute. The national code is a guide, which must be adopted by law in the locale where it will become effective.

The elevator system is made up of multiple components which affect the design of the building structure. Key components include the hoist machine, controls, guide rail system, the elevator car in which passengers ride, and safety systems which stop the elevator under certain conditions. A diagram of the key components is shown in *Figure 2*.

When traction elevators are included in the building design, the elevator hoist machine is nearly always located above the elevator hoistway. This standard configuration is most cost effective and it's design proven to be safe and reliable.

Loads

Machine support beams or structural concrete slabs on which the hoist machines are mounted are used to provide permanent support for elevator machinery. Static loads, including the machine, the floor supported, and the tension in all loads on cables, can approximate 20-to 100,000 pounds per hoist machine. Elevator submittal information will include the static loads of all suspended equipment as required by code. Preliminary loads may also be provided by a sales person or consultant and compared to submittal data. The elevator machine beams are provided by the elevator contractor. The rigidity is controlled by the elevator code. The elevator machine beams and the related structural support deflection cannot exceed L (the length of the beam)/1666. Code historical records cannot be located to verify the intent of the Code committee with respect to this deflection criteria. It apparently was the intent of the Code committee to "have a stiff set of beams." Designers should be aware that the practical limit for beam length with this deflection criteria is about 20 feet.

Machine beam loads are distributed around the perimeter of the hoistway. Elevator contractors like simple beam connections with beams resting on an angle, or in a recess. However, the structural engineer is responsible for the design of the connection. Beams can be located for efficient connection. Beams can be below the machine room floor at convenient elevations for support or coped in to structural framing. Elevator contractors can provide blocking to locate the hoist machine at the proper elevation in relationship the machine room floor. Machine beam top flanges must be flush or below the floor. The code prescribes no tripping hazards. The machine room floor load is generally not supported by the machine beams, as the elevator manufacturers do not wish to be responsible for carrying the floor load on their beams.

Dynamic (Impact) loads from elevator emergency stops are also provided on elevator shop drawings. These loads can be distributed on the overhead structure or onto the guide rail system. Elevators must travel in a nearly absolute vertical path. This ensures the car sill to hoistway sill distance will be maintained at a safe ¾- to 1¼-inch, the maximum allowed by code. A T-section elevator rail provides precise guidance of the car and counterweight in the hoistway.

Guide rails are a rigid column, bottom to top of the elevator travel. Rails are connected to the building structure with steel brackets provided by the elevator installer. Guide rail supports are used to provide lateral support of the elevator manufacturer-provided guide rails. Supports are generally provided at the building floors. Additional intermediate supports are provided where the guide rail cannot meet code-based deflection and moment of inertia criteria. Spans for standard rails are generally 12-14 feet and much less in areas requiring seismic design criteria. Rails are available in different strengths and sizes which may enable installation without intermediate supports. However, the elevator industry has become less and less willing to engineer

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Figure 1. Gearless.

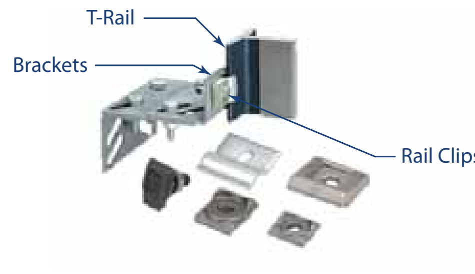

Figure 2. Guiderail bracket components.

unique applications and will avoid providing non-standard configurations if possible. Regardless, designers should be persistent and ask for problem solving assistance.

Building structure, horizontal beams, or vertical tubes provide mounting locations for the elevator rail brackets. Brackets can be installed with steel fasteners, but most often are welded into place. A certified welder must complete this connection as prescribed by the elevator code. Allowable deflections for rail supports as required by the elevator code are ⅛-inch under normal loading and ¼-inch maximum with seismic activity. Counterweight rails have the same design criteria, but have lower loads; counterweights are not the same mass as the elevator car. Guide rail loads for normal and seismic applications are provided on elevator shop drawings.

Depending on the hoistway construction type, guide rail attachments may be embedded plates in concrete or steel spanning between floors. Additional coordination may be required between architectural and structural disciplines where a fire-rated hoistway wall is required. There are varying opinions about fire resistance where a tube or column interrupts a rated wall assembly.

Connection of the rails to the brackets is provided by steel clips. The design of these clips allows the rails to act like a rigid column and permits rails to move. Connections also prevent the rails from being displaced as the building moves and flexes over time due to age, settlement, and even temperature changes over the course of a day.

Safety Components

All elevators are required by code to have a means to arrest an elevator car moving in the down direction at a certain speed above the design speed. At 10% above contract (design) speed the hoist motor is shut off. At 15% above contract speed, the car safeties engage, via a clamping action on the guide rails, and the car is stopped. This clamping action transmits a vertical force into the rail columns, which are resting on the pit floor. Elevator submittals indicate the impact load of safety operation on the pit floor.

Most modern elevators include a device which senses un-intended car movement, in either the up or down direction. This device will stop the moving elevator very quickly via a separate machine mounted brake. Loads from this occurrence are considered in the machine beam reactions.

Should an elevator over-speed in the down direction and the car safeties do not function, at the bottom of the hoistway are buffers mounted on the pit floor. These large "shock absorbers" provide a code dictated slowdown, stopping the car if it proceeds past the bottom landing at speed.

Installation and Access

To facilitate equipment installation and repair, elevator manufacturers request that hoist beams be provided. Hoist beams provide an attachment point for lifting motors, an elevator car, rails, or other components during initial installation and later if required for equipment repairs. Elevator contractors provide a recommendation for beam capacity with their equipment submittals. Hoist beams do not support moving equipment, so impact loads are not a design consideration. The top surface of the hoist beam should be located at least 2 inches below the roof or surface above to allow placement of a clamp, trolley, or rigging. The bottom of hoist beams and any other mechanical or fire protection equipment must not encroach into the code prescribed minimum machine room height, 7 feet. Hoist beams are typically centered over the hoistway.

Elevator ride quality is affected by the accuracy and precision of the guide rail installation. Building structures to which the rails are connected also must be installed accurately, with nearly perfect vertical plumbness. Elevator contractors generally request, via shop drawing details, the hoistway not vary from plumb by more than 1 inch per 100 feet of vertical travel. Elevator ride quality can also be affected by the buffeting of the car when air is "pushed" by the moving cab. At speeds of 700 fpm and higher, hoistways should be larger than standard dimensions to provide space for the air disturbed by the moving car to be cushioned without causing the car to move erratically. Hoistway sizes should be increased by a minimum of 8 inches in overall width and 6 inches front-to-back to allow for air movement. Increasing sizes of hoistways for multiple elevators in a common shaft is generally not required; multiple hoistways mitigate this problem.

In areas where building construction must be designed to consider seismic activity, elevators also must be designed to avoid equipment damage and more importantly to prohibit the car and counterweight from being dislodged from their guide rails and striking adjacent structure , or worst case, the car and counterweight colliding. In seismic areas, hoistways are widened by a minimum of 4 inches and deepened by 2 inches to allow for strengthening of the rail system and its structure.

Industry Advances

New technology is changing the elevator industry. All major elevator companies have designed and now aggressively market Machine Room Less (MRL) elevators. In this configuration, the hoist machine which propels the car and counterweights is located in the hoistway rather than above the hoistway in a separate space. Machines are mounted on a structure spanning the top of the hoistway, and in some cases, on the guide rails, which carries the machine loads to the pit floor. This configuration saves some space, though most jurisdictions require a separate secure control space for the elevator controller. Hoistway sizes for the MRL equipment are slightly wider than conventional equipment 4 to 6 inches, and vary significantly by manufacturer.

In heavily populated taller buildings, moving hundreds of persons during a peak period can be challenging. Control algorithms have improved handling capacity and system throughput. However, even the most sophisticated destination based dispatch systems, where users enter destinations via a keypad or screen cannot always handle the highest loads likely. In tall and supertall buildings with Skylobbies, double deck elevators with two connected cabs can improve service. As these cars and the suspended load they represent are substantial, hoistways are at least 12 inches wider and all elevator loads increase. One company offers two elevators operating independently in the same hoistway to improve service and traffic handling capacity. Hoistways for this equipment are also larger to provide room for duplicate cables, wiring, the cars, and even two hoist machines at the top of the hoistway. This system is the same width as the double deck configuration. None of the systems with two elevators in the same hoistway have currently been installed in North America.

Conclusions

As buildings become taller with many groups of elevators, evaluation of the space required for hoistways, machines and controls becomes important. Useable and rentable space available affects the financial viability of the building. Elevator hoistways and related equipment can be stacked, or limited to the footprint of the hoistway, with careful planning. However, this has become more difficult as code revisions now require all equipment to be safely maintainable. Any device requiring maintenance must have a minimum of 18 inches of clear space around it. Also, elevator equipment space must be 7 feet clear height to meet code. Stacking of controllers above machines can be difficult and is dependent on building floor heights and structure. For very high speed, high capacity machines, taller equipment spaces are required. Some of the largest machines may require a 12 foot clear height equipment space.

Additionally, codes periodically change to ensure the safety of first responders and the riding public. Newest codes will require a means to evacuate building occupants using elevators. In some jurisdictions, elevators must be "waterproof" so they can remain useable in a fire. Equipment for firefighter's lifts must be separated and preserved to allow fire fighters full use of elevators in an emergency. Also, elevator speed and building height effect emergency use. Model building codes are requiring the maximum time for an elevator to travel to the top floor of 60 seconds. Elevator car sizes may be larger to accommodate emergency equipment and the first responder team.▪

Much of the information in this article also applies to traction elevators in low and mid-rise buildings.