(door leaf and all pieces of equipment mechanically coupled to it) shall be limited to 10 J (88.5 in-lb), computed for the average door speed. The average door closing speed shall be calculated by measuring the time required for the leading edge of the door to travel from a point 25 mm (1 in.) away from the open jamb to a point 25 mm (1 in.) away from the point of closure of the doors. Demonstration of compliance by test in lieu of calculation may be provided.
5. Initiation of platform edge door closing shall be annunciated by audio and visual warning signals, as specified in Section 6.3.2.
6. Space between the platform doors and the vehicle doors shall be designed to prevent door closure when passengers are in the space between the vehicle doors and the platform doors, unless the gap is less than 130 mm (5 in.) from the platform level up to 1.1 m (42 in.) above the platform level.
7. Vehicle and station platform door opening and closure shall be coordinated per Section 5.2.3.

10.2.2 Intrusion Control System An intrusion control system, when provided, shall include barriers with a minimum height of 1.1 m (42 in.) and automatic horizontal sliding doors or gates and shall meet the following requirements:

1. Doors or gates shall be compatible with the requirements of Section 5.2.2, with height at least equal to that of the associated barriers.
2. Platform edge barriers, door or gate assembly, supporting tracks, and linkages shall withstand a force of 1,110 N (250 lb) applied at right angles to the panel and 1 m (3.3 ft) above floor level, distributed over an area of approximately 10 cm × 10 cm (4 in. × 4 in.), without permanent deformation or binding of the door or gate mechanism.
3. Where glass is used in barriers, doors, or gates, the glass shall comply with the requirements of ASTM C1048-04 (2004) and ASTM C1036-06 (2006b); ANSI Z97.1-2004 (2004); and 16 CFR 1201. Markings as specified in ANSI Z97.1-2004 (2004) shall be on each separate piece of glass and shall remain visible after installation.
4. Doors or gates shall comply with Sections 5.1.10 and 5.1.11 and all applicable requirements of Section 7.8 regarding locking, closing forces, obstruction detection, and emergency egress. A keyed platform side-lock release shall be provided to allow authorized access to the guideway for maintenance and evacuation purposes. Moreover, to avoid any injury, the kinetic energy of the moving parts (door leaf and all pieces of equipment mechanically coupled to it) shall be limited to 10 J (88.5 in-lb), computed for the average door speed. The average door closing speed shall be calculated by measuring the time required for the leading edge of the door to travel from a point 25 mm (1 in.) away from the open jamb to a point 25 mm (1 in.) away from the point of closure of the doors. Demonstration of compliance by test in lieu of calculation may be provided.
5. Door or gate closing shall be annunciated by audio and visual warning signals, as specified in Section 6.3.2.
6. Space between the doors or gates and the vehicle doors shall be designed to prevent closure when passengers are in the space between the vehicle doors and the doors or gates, unless the gap is less than 130 mm (5 in.).
7. Vehicle and station platform door openings and closings shall be coordinated per Section 5.2.3.
8. Openings or spaces between elements of the door, gate, or barrier shall be designed such that a 100 mm (4 in.) diameter sphere will not pass through. Fences and gates shall be constructed to inhibit contact with the vehicle per Section 7.2.

10.2.3 Intrusion Detection System If provided, an intrusion detection system shall be capable of detecting the intrusion of a sphere 0.3 m (1 ft) in diameter or larger weighing 9 kg (20 lb) or more, falling or otherwise passing from the platform to the guideway at any open location, at a height between platform level and 1.1 m (42 in.) above the platform surface.

When activated, the detection system shall initiate the following:

1. Command for appropriate braking for trains entering or approaching the station, as determined by a hazard analysis per Section 3.1.2.1;
2. Command to stop any moving apparatus on the guideway exposed to potential contact by the intruder (for example, drive ropes) in the vicinity of the detected intrusion; and
3. Alarm to central control.

The procedures used to reset the detection system and to restore traffic after an intrusion detection shall be analyzed through a hazard analysis per Section 3.1.2.1.

10.3 EVACUATION OF MISALIGNED TRAINS

A means shall be provided to allow egress from a misaligned train onto the station platform. Such means shall meet the requirements of Section 11.3. Where auxiliary egress doors or gates are used, a latching mechanism shall be provided on the guideway side to allow passengers to exit onto the platform. Permissible misalignment shall be per Section 5.2.2.

Access shall be provided for authorized personnel to the interior of each car of a train at any location along the guideway, including any location within the station. If auxiliary egress doors or gates are used for access through station barrier walls, then a keyed platform side-lock release shall be provided in these auxiliary egress doors or gates to allow authorized access to the cars. The opening of any such auxiliary egress door or gate shall result in the facility door detection and response requirements specified in Section 5.1.9.

10.4 EMERGENCY LIGHTING AND VENTILATION

For APM station platforms located within airport terminals or office, retail, entertainment, or other such buildings, the station lighting and ventilation shall be in accordance with local building codes, as applicable, and NFPA 101 (2006), Sections 7.9 and 9.2. For interpretation of such building codes, the APM platforms shall be treated, for lighting and ventilation issues only, as elevator lobbies. (Refer also to Section 10.5.1, Fire Detection.)

For freestanding stations dedicated to the APM system, the station emergency ventilation and emergency lighting provisions shall comply with NFPA 130 (2017), Sections 5.4.7 and 5.3.11, respectively. Lighting fixtures shall be designed as vandal resistant.

10.5 FIRE PROTECTION

A fire protection system shall be provided. Station design may be considered in combination with platform doors to provide fire-rating compliance, as approved by local fire authorities.

10.5.1 Fire Detection All stations and associated equipment rooms shall be provided with smoke and/or heat detection and alarm devices that shall be annunciated on a fire monitoring display in central control. Upon activation of a smoke or fire alarm, appropriate automatic or operational procedures shall be implemented to address the hazards associated with fire or smoke as required by a hazard analysis per Section 3.1.2.1.

10.5.2 Fire Containment Station platform barriers and doors, if intended to serve as fire barriers, shall comply with the requirements of NFPA 130 (2017), Sections 5.2.4.2 and 5.2.4.3. The fire separation of all stations shall be based on an engineering analysis of potential fire exposure hazards conducted in accordance with Section 3.1.2.1, Hazard Analyses.

10.5.3 Fire Suppression A fire suppression system, if specified by the authority having jurisdiction, shall comply with local building codes and/or NFPA 130 (2017).

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CHAPTER 11
GUIDEWAYS

The requirements given in this section apply to all rigid guideways: elevated, at-grade, and underground.

Systems suspended by wire rope or cable are addressed by the requirements given in ANSI B77.1-2006 (2006).

The guideway shall be designed and constructed in such a way that the ride quality criteria and the vehicle clearance restrictions are met along the entire alignment. The guideway shall be designed to support all loads and forces associated with vehicles, vehicle interfaces, the environment, and any other facilities affixed to the guideway.

11.1 BLUE LIGHT STATIONS

Blue light stations shall be provided as defined in Sections 6.1.2 and 9.1.1 of this standard and in NFPA 130 (2017), in Section 6.4.2 and Section 10.4.3 in its entirety.

11.2 INTRUSION PROTECTION AND DETECTION

The system shall be designed to protect against unauthorized persons or foreign objects entering the vehicle dynamic envelope. This protection shall be in the form of fencing or other suitable barriers, as determined by a hazard analysis per Section 3.1.2.1.

Where deemed appropriate from the hazard analysis per Section 3.1.2.1, intrusion detection devices shall be provided to alert the system to unauthorized access.

11.3 EMERGENCY EVACUATION AND ACCESS

The automated people mover (APM) guideway emergency evacuation and access shall be designed in accordance with the requirements of NFPA 130 (2017), Sections 6.3 and 6.4.1. In addition, the APM guideway shall meet the following two stipulations:

1. Under NFPA 130 (2017), Section 6.3 regarding evacuation of passengers from a disabled train, guidance and control by authorized personnel shall involve voice communication by the central control operator, and such involvement shall be sufficient to meet the intent of Section 6.3.
2. If any passenger activates the door release within any vehicle, creating a condition allowing passengers to exit the vehicle onto the guideway or its associated emergency walks, or other suitable means of evacuation, passengers shall be protected, as determined by a hazard analysis per Section 3.1.2.1. Hazards shall include making contact with an energized power rail or any other device of dangerous electrical potential and entering any portion of the guideway where other vehicles are still moving.

All station or guideway doors that do not provide emergency egress shall be so identified and clearly labeled “Not an Exit.” Emergency egress doors shall not be locked on the inside at any time. Emergency exits shall have the capability of being readily opened from the outside by the fire department or other rescue personnel.

11.3.1 Tunnel Guideway Emergency exits shall comply with the requirements of NFPA 130 (2017), Section 6.3. This requirement includes doors, exit hatches, and emergency lighting. When interpreting NFPA 130 (2017) requirements, a *point of safety* shall be defined as an enclosed fire exit that leads to a public way or safe location outside the structure, or an at-grade point beyond any enclosing structure, or another area that affords adequate protection for passengers.

11.3.2 Surface Guideway For an at-grade or any unroofed structure other than elevated structures, the emergency access and egress should comply with NFPA 130 (2017), Sections 6.3 and 6.4.1.

11.3.3 Elevated Guideway Elevated structures are all structures not defined in this standard as surface or underground structures. For elevated structures, the emergency access and egress should comply with NFPA 130 (2017), Sections 6.3 and 6.4.1.

Passenger egress from elevated guideways shall comply with NFPA 130 (2017), Section 6.3. An acceptable *other suitable means* to using an elevated emergency walkway shall be a means that evacuates the maximum number of passengers who can be in a maximum-length train to a point of safety within no more than 15 min from the time the evacuation is initiated. The means and duration shall be subject to a hazard analysis per Section 3.1.2.1.

11.4 FIRE PROTECTION

For tunnels, the fire protection provisions of NFPA 130 (2017), Sections 6.4.4 and 6.4.5 shall apply. Tunnel construction materials shall comply with Sections 6.2.2, 6.2.3, and 6.2.6 of NFPA 130 (2017).

A fire suppression system, if specified by the authority having jurisdiction, shall comply with local building codes and/or NFPA 130 (2017).

11.5 SIGNAGE

Signage shall be provided along the guideway and in the adjacent right-of-way to inform passengers, operating personnel, and emergency services personnel of features that may be critical for safe evacuation or to minimize the severity of a life-threatening incident and to enhance system operation.

The types and location of signs shall comply with the requirements of NFPA 130 (2017), Section 6.3.5. Where not otherwise specified, ANSI 117.1-2003 (2003) should be consulted for signage lettering size, color, and contrast. In addition, the following types of signage shall be provided:

1. **Emergency Exit**: Emergency evacuation routes to the point of safety shall be provided with the following signage: (a) direction to nearest exit [signs spaced no more than 30 m (100 ft) apart], (b) designation of exit, (c) instructions for using the exit, and (d) warning sign of potential hazards in the exit area. Emergency exit signage shall be visible at all times.
2. **Exposed Power-Delivery Device**: Clearly visible signs shall be provided to warn of hazard greater than 50 V presented by exposed power rails or other exposed power-delivery devices, in accordance with NFPA 130 (2017), Section 6.3.5.1. Signs shall be provided on the guideway at station locations and at intervals of no more than 30 m (100 ft) along the guideway.
3. **Location Information**: Location information shall be provided on, and visible from, the guideway at intervals of no more than 100 m (325 ft).
4. **Power Section**: Boundaries of each power section shall be clearly marked.

11.6 EMERGENCY LIGHTING AND VENTILATION

For underground systems, lighting provisions shall be in accordance with NFPA 130 (2017), Section 6.3.5. Underground systems shall comply with the ventilation requirements of NFPA 130 (2017), Section 7.8.

For elevated and at-grade systems, the egress route shall have a level of illumination of no less than 2.7 lux (0.25 ft-candles).

11.7 EMERGENCY POWER SUPPLY

For underground systems, the power supply for emergency ventilation provisions of NFPA 130 (2017), Section 7.8, shall apply.

11.8 GUIDEWAY ALIGNMENT

The guideway shall be designed and constructed in accordance with vehicle ride quality criteria per Section 7.7.3.

Horizontal alignment may consist of any combination of straight (tangent) sections, spiral transitions, and curved sections.

The effects of centrifugal forces, superelevation, ride comfort criteria, and the related limitation of operating speed shall be considered in establishing the guideway horizontal alignment. Vehicle turning restrictions shall also be considered.

Vertical alignments may also consist of any combination of straight sections, spiral transitions, and curved sections. The effects of centrifugal forces, ride comfort criteria, and vehicle geometric limitations to vertical curve radius (crest and trough) shall be considered in establishing guideway vertical alignment.

When the vehicle is stopped at a station, the guideway shall be designed so that the vehicle floor shall not be inclined by more than 1% in any direction with respect to a horizontal plane.

When the vehicle is stopped at any other location along the guideway, (a) the angle at which the vehicle floor is inclined laterally shall not exceed 12% with respect to a horizontal plane, and (b) the angle at which the vehicle floor is inclined longitudinally shall be limited by the normal longitudinal limits for maximum sustained acceleration, including the effects of grade, per Section 7.7.3.1.1.

11.8.1 Clearances The vehicle dynamic envelope per Section 7.2 shall be separated from any other vehicle dynamic envelope on an adjacent trackway by at least 100 mm (4 in.).

Nonstructural system components that provide less clearance shall be permissible subject to a hazard analysis per Section 3.1.2.1.

The vehicle dynamic envelope shall be separated from any fixed structure by at least 100 mm (4 in.). Station platform edges and APM system equipment that are designed to physically interface with the vehicles are excluded from this requirement.

The maximum allowable clearance between the vehicle threshold and the station platform edge shall be per Section 7.3.

If the vehicle is designed to come in contact with the platform edge under normal operating conditions, the platform edge shall be designed so that the vehicle ride quality criteria given in Section 7.7.3 are met, except that the jerk limit in all directions shall be $0.1g$/s for standing passengers.

If the vehicle dynamic envelope is such that the vehicle may come in contact with the platform edge under failure conditions, the platform edge and/or vehicle shall be designed to allow no more than cosmetic damage to the vehicle when the vehicle impacts the platform edge while operating at design speed.

11.8.2 Operating Equipment Interfaces The guideway shall provide support and guidance to passenger vehicles and service vehicles throughout the APM system. The design of the guideway shall accommodate all elements of the APM system that are to be installed on the guideway.

11.8.3 Drainage If the guideway design is such that water may accumulate on the surfaces, provisions shall be made in the design for draining the water. The drainage system shall route the water to a location acceptable to all local, state, and national codes and regulations and shall not cause drainage water or hazardous accumulations of snow or ice to fall onto pedestrian or vehicular paths.

In cases in which a drainage system is included in the design of the guideway, surfaces shall be sloped toward the drains with a minimum 1% slope (excluding the running surface as long as provisions are made for minimizing water accumulation on the running surface).

The drainage system shall be designed to operate in all environmental conditions per Section 2.1.

11.9 STRUCTURAL CRITERIA

The guideway for an APM system shall comply with the following structural design requirements and the applicable requirements in local codes. The term *selected code* in this section refers to the legally binding local codes or either of the following two codes: AASHTO, LRFD Bridge Design Specifications, and Eurocode 1990–1999.

See Section 1.4 of this standard for the version of code to be used with this standard. The need for additional or overriding design requirements specific to the project and the APM system being used shall be assessed and incorporated into project-specific design criteria to supplement the codes as required.

Note: ASCE does not pass judgment on the adequacy or lack thereof of any local codes used in APM structural design.

11.9.1 Loads and Forces The guideway shall be designed for the following loads and forces, with appropriate consideration of point loads, distributed loads, and interrelated loads that occur for a specific technology's suspension, propulsion, and entrainment characteristics. Final design shall incorporate loads as defined by the APM system supplier.

Dead Load (DL): Dead load shall consist of the weight of all permanent fastened material and equipment. Dead load shall consider allowance for future additions to the structure. Note: See Commentary Section 11.10.1, Future Increase in Live Load.

Live Load (LL): Live load shall consist of the weight of the applied load of one or more trains under fatigue, normal, crush-loaded, and failure conditions as defined by the installation-specific hazard analysis, including any specified push / pull retrieval capability, plus any additional services and emergency equipment included in the system that might be brought out on the guideway for maintenance or during failures. Trains consisting of different numbers of cars shall be considered, based on the specific technology. Multiple trains shall be considered if the guideway supports multiple lanes. The weight of the applied load of passengers on the emergency walkway(s), if provided, also shall be considered. Live load shall be defined as AW0 (empty vehicles), AW1 (design load), AW2 (maximum operating), and AW3 (crush) as defined in Section 7.1 of this standard and AWF (fatigue) as defined following. Crush load shall consider both a static AW3 load and a dynamic AW2 load.

AWF: Average operating load over the fatigue life of the system as determined by the expected ridership and specified operating scenarios. In lieu of calculating an average operating load, AW1 shall be used. Refer to Sections 7.1, 11.9 and the commentary of Section 11.10 for factors to consider when calculating AWF.

Pedestrian or Walkway Load (PL): Live load on service or emergency walkways shall be at least 5.0 kPa (100 lb/ft^2). The total live load transferred from the walkway to the guideway need not exceed the total weight of evacuated passengers. Live load on walkways shall be combined with a static AW0 load on one track. In case of multiple tracks, the additional tracks shall be loaded with static AW2 loads.

Vertical Impact Forces (IV): Ratio of vehicle crossing frequency (*VCF*) to span fundamental frequency (*SF*) shall be computed for each span, where:

- ***VCF*** is defined as the number of spans crossed per second by a vehicle, computed as vehicle speed in meters per second (feet per second) divided by span length in meters (feet).
- ***SF*** is defined as the lowest guideway natural frequency excited by vertical train loading on the span computed based on guideway dead load mass and guideway structural stiffness properties.

Vehicle Frequency *(VF)* is defined as the lowest natural frequency of a vehicle excited by vertical loading.

For values of *VCF/SF* less than 0.2, the minimum dynamic load allowance (*IM*) applied to the vertical live load shall be 0.1.

For values of *VCF/SF* greater than or equal to 0.2 but less than or equal to 0.3, the minimum dynamic load allowance (*IM*) applied to the vertical live load shall be calculated as follows:

$$IM = \frac{VCF}{SF} - 0.1 \tag{11-1}$$

For values of *VCF/SF* greater than 0.3, a dynamic analysis shall be performed considering the dynamic properties of the guideway and the vehicles (*VCF, SF*, and *VF*). The dynamic analysis shall be used to determine guideway deflections, dynamic load allowances, and vehicle vertical accelerations. However, the dynamic load allowance (*IM*) shall not be less than 0.2.

Centrifugal Force (*CF*): Centrifugal force acting radially through the center of gravity of the vehicle on curved track shall be calculated as follows:

$$CF = V^2 LL/R(\text{SI units}) \text{ or } CF = V^2 LL/32.2R\,(\text{English units}),$$

where V is the design speed for the particular curve in meters per second (feet per second); LL is the vehicle live load in kilograms (pounds force), and R is the radius of the curve in meters (feet). The effects of superelevation on vertical and lateral loads shall be taken into account. The case of a stationary train on a superelevated curve shall also be considered.

Longitudinal Force (LF): Guideway shall be designed for maximum longitudinal forces caused by acceleration, service deceleration, and emergency deceleration, including grade effects, applied to the live loads. In addition, the guideway shall be designed for severe loads caused by suspension, guidance, or propulsion system failure as determined from a hazard analysis in accordance with Section 3.1.2.1 of this standard. The longitudinal force due to normal traction and braking, and force due to emergency braking shall be as specified Table 7-1 for preliminary design. These forces shall be based on design values supplied by the system supplier for final design.

Horizontal Impact Force or Steering Force (IH): Forces from vehicle steering shall be applied to the guidance and running surfaces. The magnitude of these forces shall be based on the steering characteristics of a maximum AW2-size train, with consideration for abnormal steering. Steering force shall include forces caused by steering misalignment, hunting, and the difference between the direction of vehicle motion and the steering angle. This force shall be taken as 10% of the AW2 load acting at the level of the guiderail or at the centroid of the vehicle in the absence of a guiderail for preliminary design. Refined values based on design values supplied by the system supplier shall be used for final design.

Buffeting Force (BF): Effect of buffeting forces when a maximum-length train enters a narrow, closed passage shall be investigated, and these pressures shall be treated as a special condition of wind load for load combinations.

Thermal Force (T): Provisions shall be made in the structural design for stresses and deformations occurring from ambient temperature changes, radiant and solar heating, and radiation cooling. Where applicable, stresses induced by heating provisions for ice and snow conditions and by differential movement of guideway elements shall be included. Special consideration shall be given to systems operating in a controlled environment.

Rail Structure Interaction Forces (RSI): Forces due to differential temperatures between the guideway structure and steel rail (either main rail or guiderail) are a special case of thermal forces and shall be considered in case of continuous welded rail directly fastened to the guideway. RSI forces when computed shall be used in lieu of thermal forces described above. Ambient temperatures and the range of temperature to be considered for both guideway and rail shall be determined by a rational process based on historic local climate data, as described in Section 2.1. Rail lay temperature shall be determined in consultation with the governing agency and systems supplier. Interaction forces need not be considered in cases where the rails have expansion joints corresponding to joints in the guideway superstructure.

Wind Loads on Structure (WS): Wind loads on the elevated guideway only shall be computed and applied in accordance with the selected code. The maximum wind speed for survival as defined in Section 2.1.2 of this standard shall be used. Both horizontal and vertical wind effects shall be considered.

Wind loads on the exposed areas of the vehicle in combination with the wind loads on the elevated structure shall be computed using the same method as used for the wind load on the structure.

These loads shall be based on the maximum wind speed for manual operation as defined in Section 2.1.2 of this standard. Only horizontal wind effects on the vehicle need to be considered.

For systems in which empty vehicles are stored on the elevated guideway or parked on the elevated structure when the system is shut down, maximum wind speed for survival as defined in Section 2.1.2 of this standard shall be used to calculate the wind effects on both the elevated structure and the vehicles.

Snow and Ice Loads (IL): Loads resulting from freezing rain and from consolidation of snow on the guideway superstructure shall be included as appropriate, considering the environmental conditions per Section 2.1.3 of this standard and the potential for buildup based on the configuration of the guideway.

Loads on the guideway caused by ice pressure or floating ice shall be computed and applied in accordance with the selected code.

Earth Pressure (EP): Earth pressure shall be computed and applied in accordance with the selected code.

Seismic Force (EQ): Seismic forces on elevated guideways shall be computed and applied in accordance with the selected code.

Seismic forces for underground structures must consider a site analysis for ground shaking, fault rupture, regional tectonic movements, landslides, liquefaction, and differential consolidation of sediments. In areas where these design parameters are not available to the geotechnical or underground designer, a seismic hazard evaluation shall be conducted to assess the above risk and provide ground motions, site responses, and racking parameters for design of structures. For structural analysis, the earthquake loading may be applied as a distortion or racking, superimposed on the static loading conditions.

Note: For areas with high seismic activity, local codes and governing authorities shall be consulted. Consideration shall be given to include the vehicle mass on the structure during seismic events.

Stream Flow (SF): Loads resulting from flowing water shall be computed and applied in accordance with the selected code.

Vehicle Collision (CT): Columns located within a distance of 10 m (30 ft) from the edge of a roadway shall be protected with a structural traffic barrier or designed in accordance with the selected code.

The possibility of overheight vehicles colliding with a guideway beam shall be considered for guideways with less than 5 m (16.5 ft) clearance over existing roadways.

Construction Loads (CL): Loads caused by construction equipment and materials that may be imposed on the guideway structure during construction should be considered. Additionally, transient load effects during construction caused by wind, ice, stream flow, and seismic events should be considered commensurate with the expected duration of the particular construction stages.

Other Guideway Equipment Forces (QF): Guideway loads and forces caused by attached wayside equipment, such as propulsion cables, sheaves, linear induction motors, and guideway switches, as applicable, shall be considered.

Derailment Loads (DR): In the absence of more exact information from the system supplier, derailment loads shall be considered as follows.

1. All axles of any one truck shall be assumed to be derailed. A single truck derails initially and may drag additional axles or the entire train off the guideway.
2. The derailed train shall be positioned parallel to its original position and laterally displaced by a maximum of 915 mm (36 in.) or as limited by geometric and physical conditions. Lateral displacement shall be varied to cause maximum effects in the element under consideration.
3. Different train configurations shall be considered to determine the controlling condition for the element under consideration.
4. Vertical derailment impact shall be 100% on the axles of the derailed truck and equal to normal vertical impact on the remaining axles of the train.
5. Horizontal derailment impact shall be at least 40% of the total car weight acting on the axles of the derailed truck. The remaining axles shall have normal horizontal impact.
6. Structures carrying more than one track shall be investigated for one derailed train and a second static train with AW2 load on any of the other tracks so as to cause maximum loads in the element under consideration.

Additional trains on the structure need not be considered in conjunction with a derailed train.

Rail Break Force (RB): This force need only be considered in case of structures subject to rail structure interaction described above which often occurs at minimum temperature. The breaking of a rail results in the sudden release of strain energy. Any one rail shall be considered to break at a time, and the break can occur anywhere on the structure.

Note: From practical considerations, analysis may be restricted to breaks at existing expansion joints in the supporting superstructure.

Note: In addition to analyzing the forces caused by a break in the rail, the gap in the rail should also be considered. The allowable gap in the rail is a function of the wheel diameter and train control system and should be determined in consultation with the system supplier.

Other Forces: Forces as defined by the selected code, such as Creep (C), Shrinkage (S), Buoyancy (B), Differential Settlement (DS), and Prestressing (PS) shall be determined per the selected code or by rational methods. Buffer Reaction (BR) shall be considered in cases where a terminus arrangement is provided on the guideway structure. Loads and point of action shall be per the train supplier.

11.9.2 Load Combinations Loads and forces shall be investigated in combination as specified in the selected code. If the selected code is AASHTO, then Section 3.22 of the AASHTO *Standard Specifications for Highway Bridges*, 17th edition, 2002, or in Section 3.4 of AASHTO *LRFD Bridge Design Specifications* 8th edition, 2017, shall be used with the single exception that the live load factor in load combination "Group I" of AASHTO *Standard Specifications for Highway Bridges*, 17th edition, 2002, shall be changed from 1.67 to 1.35. If the selected code is other than AASHTO, live load factors for load combinations shall be shown by calculation to produce equivalent APM loadings to those obtained using the AASHTO approach.

Note: This live load factor has been reduced because the APM empty vehicle and passenger loads are known. The load magnitude uncertainty is therefore reduced relative to that of live loads on highway bridges. Therefore, the live load factor in the first load combination only of AASHTO *Standard Specifications for Highway Bridges*, 17th edition, 2002, has been reduced.

11.9.3 Design and Analysis Deflections and Tolerances: Guideway design and construction tolerances shall be coordinated with the system designer to maintain operational requirements and achieve the ride quality requirements and clearance requirements of Section 7.7.3 of this standard.

Fatigue: Fatigue design shall be in accordance with the selected code. The number of cycles of maximum stress range caused by AWF operating load to be considered in the design of the guideway shall correspond to the number of cycles in the proposed project operating scenario considering (1) number of days of operation, (2) daily hours of operation, and (3) frequency of trains (headway) during each operating period. Refer to the commentary for factors to consider when calculating the number of cycles. In the absence of any specified fatigue life in the project requirements, fatigue life as defined by the reference codes shall be used.

The running and guidance elements shall be designed, with recommended maintenance, for at least a 20-year life while meeting the specified system operating criteria, unless explicitly specified otherwise by the owner.

Structural Deformation and Settlement: All structural deformations, including differential foundation settlement, shall be considered in the structural behavior of the guideway and vehicle guidance provisions. The control of deformation to maintain acceptable ride comfort requirements per Section 7.7.3 of this standard shall be considered in the structural design of the guideway.

11.10 COMMENTARY ON SECTION 11.9

11.10.1 Future Increase in Live Load The potential for future increase in live load may be considered in the design, if specified in the project technical provisions, for the following items.

1. Increase in car weight for future replacement and/or upgrades,
2. Increase to the applied load of passengers due to passenger weight estimation increasing over time,
3. Increase in train length due to passenger demand increase over time,
4. Increase in train frequency or hours of operation with closer headway, and
5. Service vehicles.

11.10.2 Reduction of Live Load Factors This standard allows for specified reduction of live load factors to be used in load combinations specified by the selected code. APMs generally operate with controlled vehicle loads and with controlled placement of the vehicles. Accordingly, the maximum load imposed on an APM guideway may have less uncertainty than other design scenarios for which the selected code was written. This standard allows live load factors to be reduced as specified in Section 11.9.2.

If the selected code does not have suitable combinations, Table 11-1 or ACI 343.1R-12 may be used to develop load combinations.

Table 11-1. Load Combinations.

Load combination limit state	DL, EP, CL	PS, C, S	LL, IV, IH, PL, BR	CF, BF	LF	SF, B	WS	WL	T, RSI	TG	DS	EQ	CT	RB	DR	IL
Strength I	0.9/1.25	0.9/1.00	1.35	1.35	–	1.00	–	–	0.50/1.20	–	1.00	–	–	–	–	–
Strength II	0.9/1.25	0.9/1.00	1.35	–	1.35	1.00	–	–	0.50/1.20	–	1.00	–	–	–	–	–
Strength III	0.9/1.25	0.9/1.00	–	–	–	1.00	1.00	–	0.50/1.20	–	1.00	–	–	–	–	–
Strength IV	0.9/1.5	0.9/1.00	–	–	–	1.00	–	–	0.50/1.20	–	–	–	–	–	–	–
Strength V	0.9/1.25	0.9/1.00	1.35	1.35	–	1.00	1.00	1.00	0.50/1.20	–	1.00	–	–	–	–	–
Extreme Event I	1.00	0.9/1.00	g_{EQ}	–	–	1.00	–	–	–	–	–	1.00	–	–	–	–
Extreme Event IIa	1.00	0.9/1.00	1.00	–	–	1.00	–	–	–	–	–	–	1.00	–	–	–
Extreme Event IIb	1.00	0.9/1.00	1.00	–	–	1.00	–	–	–	–	–	–	–	1.00	–	–
Extreme Event IIc	1.00	0.9/1.00	1.00	–	–	1.00	–	–	–	–	–	–	–	–	1.00	–
Extreme Event IId	1.00	0.9/1.00	1.00	–	–	1.00	–	–	–	–	–	–	–	–	–	1.00
Service Ia [a]	1.00	0.9/1.00	1.00	1.00	–	1.00	–	–	0.0/1.00	0.50	0.0/1.00	–	–	–	–	–
Service Ib [a]	1.00	0.9/1.00	–	–	–	1.00	1.00	–	0.0/1.00	1.00	0.0/1.00	–	–	–	–	–
Service Ic [a]	1.00	0.9/1.00	1.00	1.00	1.00	1.00	0.50	1.00	0.0/1.00	0.50	0.0/1.00	–	–	–	–	–
Service II [b]	1.00	0.9/1.00	1.30	1.30	–	1.00	–	–	1.00/1.20	–	–	–	–	–	–	–
Service III	1.00	0.9/1.00	g_{LL}	g_{LL}	g_{LL}	1.00	–	–	1.00/1.20	0.5	1.00	–	–	–	–	–
Service IV	1.00	0.9/1.00	–	–	–	1.00	1.00	–	1.00/1.20	–	1.00	–	–	–	–	–
Fatigue I - LL, IV and CF only (infinite life) [c]	–	–	1.35	–	–	–	–	–	–	–	–	–	–	–	–	–
Fatigue II - LL, IV and CF only (finite life) [c]	–	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–

Notes:
X.XX Items in gray are modified from AASHTO to reflect APM characteristics.
g_{LL} 1.0 for prestressed concrete components designed using the refined estimates of time-dependent losses as specified in AASHTO Article 5.9.5.4 in conjunction with taking advantage of the elastic gain.
0.8 for all other prestressed concrete components.
g_{EQ} Check for both No train and for One train per structure:
For dual guideway structures, a train on either the left or right track, whichever is worse.
For single guideway structures, a single train.
Service III = crack control.
Service IV = column crack control.
[a] When vehicles are in operation, vehicle speed and wind speed are determined by system requirements.
[b] Steel slip critical connections only.
[c] Fatigue load combination to be chosen based on the number of cycles and the design life of the complete system or individual components. Factors may be modified based on available test data.

Table 11-1 *(Continued)*. Load Combinations.

ABBREVIATIONS:

Load Case		Source Code
B	Buoyancy	AASHTO/ASCE
BF	Buffeting force	ASCE
BR	Buffer reaction	ASCE
C	Creep	AASHTO/ASCE
CF	Centrifugal force	AASHTO/ASCE
CL	Construction loads	ASCE
CT	Vehicle collision	AASHTO/ASCE
DL	Dead load	AASHTO/ASCE
DR	Derailment load	ASCE
DS	Differential settlement	AASHTO/ASCE
EP	Earth pressure	AASHTO/ASCE
EQ	Seismic forces	AASHTO/ASCE
IH	Horizontal impact force or steering force	ASCE
IL	Snow and ice loads	AASHTO/ASCE
IV	Vertical impact forces	AASHTO/ASCE
LL	Live load	AASHTO/ASCE
LF	Longitudinal force	AASHTO/ASCE
PL	Pedestrian or walkway load	ASCE
PS	Prestressing	AASHTO/ASCE
RB	Rail break force	ASCE
RSI	Rail structure interaction forces	ASCE
S	Shrinkage	AASHTO/ASCE
SF	Stream flow	AASHTO/ASCE
T	Thermal force	AASHTO/ASCE
TG	Temperature gradient	AASHTO
WL	Wind loads on live load	AASHTO/ASCE
WS	Wind loads on structure	AASHTO/ASCE