13.1 General

This chapter introduces the subject of tolerances as related to buildings and provides the designer with some of the basic tolerances that should be considered during the layout and design of precast concrete structures. This chapter is a cursory presentation of information that has been previously published by PCI and reviewed by the precast concrete industry. Because of this, PCI documents (see References 1 through 4) that discuss the subject of tolerances more fully should be specified in contract documents and referred to when resolving questions about tolerances.

13.1.1 Definitions

Bowing. An overall out-of-plane condition in which two opposite edges of a component, such as a panel, fall in the same plane and the portion of the panel between the edges is out of plane.

Camber. (1) The out-of-plane translation of a point within the span of a prestressed component that occurs due to the net bending resulting from an eccentric prestressing force (not including dimensional inaccuracies); (2) a built-in curvature. Camber is typically measured at midspan.

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Connection. A device for the attachment of precast concrete components to each other or to the structure to which it is attached. Connection design must account for the cumulative effects of all allowed tolerance variations.

Contract documents. General conditions, project specifications, and drawings issued on behalf of the owner by the design professionals of record (architect/engineer) and from which the project erection drawings and production drawings are developed.

Clearance. Interface space (distance) between two components. Clearance is normally specified to allow for the effects of product and erection tolerances and for anticipated movement such as deflection, volume change movement, and the like.

Clear distance. The least distance between the surface of the reinforcement and the referenced surface. The referenced surface may be the form, adjacent reinforcement, embedments, concrete surface, or other surfaces.

Concealed surface. Surface not visible during normal use of the component.

Deviation. The departure from an established reference point, line, plane, or surface measured in a direction that is perpendicular to the reference line, plane, or surface.

Dimensions. The following are several different categories of dimensions relevant to precast concrete fabrication.

- **Actual dimension.** The measured dimension of the precast concrete component after casting. The actual or as-built dimension may differ from the working dimension due to construction and material-induced variations.
- **Basic dimension.** The dimensions shown on the contract drawings or called for in the specifications. The basic dimension applies to size, location, and relative location. It may also be called the nominal dimension.
- **Working dimension.** The planned dimension of the precast concrete component obtained from its basic dimension, the necessary joint or clearance dimensions, and other adjustments.

Draft. The taper given to features of a mold or form to allow the precast concrete piece to be removed from the mold or form without damage. Draft can result in different feature dimensions between the front and back of a piece.

Drawings. The following are typical terms used by the precast/prestressed concrete industry:

- **Shop drawings**. (1) Collective term used for erection drawings, production drawings, and hardware details. (2) Diagrams of individual precast concrete components and their connecting hardware, developed from information in the contract documents. Shop drawings show information needed for both field assembly (erection) and manufacture (production) of the precast concrete components.
- **Erection drawings.** Drawings that show the relationship of the precast components and their connections in the erected structure and that provide necessary information to properly erect and connect the various components.
- **Production drawings.** A set of instructions in the form of diagrams and text that contain all of the information necessary for the manufacturer to produce the precast concrete component. These documents are usually produced by or under the direction of the precast plant engineering department or by an entity hired by the precast concrete manufacturer.

Flatness. The degree to which a surface approximates a plane (see smoothness). This tolerance is most important in wall and slab components.

Flushness. The offset relationship of an embedded plate to the surrounding concrete.

Plumb. In a vertical line.

Pretopped systems. A construction approach, typically used in the floor system of parking structures, in which the double-tee flange for the floor component is constructed to its final thickness in the plant, resulting in cast-in-place concrete topping not being required in the field.

Quality. The appearance, strength, durability, and dimensional conformance that is appropriate for the specific product, its particular application, and its expected performance requirements. Quality also refers to the totality of features and characteristics of a product and on its ability to satisfy stated needs.

Quality assurance (QA). All those planned or systematic actions necessary to ensure that the final product or service will satisfy given requirements for quality and performance of intended function. Typically, the quality assurance effort will focus on the requirements of the overall project, thereby identifying the tolerance quality control requirements for component fabrication.

Quality control (QC). Those planned actions that provide a means to measure and control the characteristics of components and materials to predetermined, quantitative criteria.

Relative alignment. The distance between two or more components in any plane, or the distance between adjacent components, or the distance between a component and a defined point or plane.

Setup. The process of preparing molds or forms for casting, including installation of materials (reinforcement and hardware) prior to the actual placing of concrete. The setup process is second only to the mold or form construction in its importance in the achievement of specified component tolerances.

Shrinkage. The volume change in concrete caused by drying that normally occurs during its curing and initial life. The expected shrinkage must be subtracted from the form setup dimensions to determine the as-cast dimensions of a component.

Smoothness. The absence of local irregularity or roughness. It does not refer to the overall shape of the component.

Specially finished structural precast concrete. A component fabricated using forms and techniques common to the production of structural components and having specified surface finishes that require uniformity and detailing more demanding than the typical requirements for structural components. See Chapter 14, Section 14.2.3 of this handbook for PCI plant certification categories.

Sweep. An overall variation in a component's horizontal alignment. This can sometimes be caused by horizontally eccentric prestress in narrow components.

Tipping. The offset relationship of an embedded plate from one edge to another.

Tolerance. The specified permissible deviation from specified requirements such as dimensions, location, and alignment. Examples are:

- the permitted deviation from a basic dimension or quantity, as in the length, width, and depth of a component;
- the range of variation permitted in maintaining a basic dimension, as in an alignment tolerance; and
- a permitted variation from location or alignment.

Tolerances, erection. Those allowable deviations in dimensions of a component's placement in the completed structure required for acceptable layout and placement of precast concrete components after they are erected.

Tolerances, interfacing. Those allowable deviations in dimensions associated with other materials or systems in contact with or in close proximity to the precast concrete.

Tolerances, product. Those allowable deviations in dimensions relating to individual precast concrete components.

Warping. Twisting of a component, resulting in overall out-of-plane curvature of surfaces characterized by all edges being non-parallel. Warping is most often a concern in panel components, although it can be a concern in other types of components, such as pretopped double-tees.

13.1.2 Purpose

Tolerances are normally established by economical and practical production, erection, and interfacing considerations, and are based on References 1 through 4. Once established, they should be shown in the contract documents, and used in design and detailing of components and connections. Architectural and structural concepts should be developed with the practical limitations of dimensional control in mind, as the tolerances will affect the dimensions of the completed structure.

Tolerances are required for the following reasons:

- **Structural —** To ensure that the structural design accounts for factors that are sensitive to variations in dimension and plumbness. Examples include eccentric loadings, bearing areas, and locations of reinforcement and embedded items.
- **Feasible —** To ensure acceptable performance of joints and interfacing materials in the finished structure.
- **Visual —** To ensure that the variations will be controllable and will result in an acceptable-looking structure.
- **Economical —** To ensure ease and speed of production and erection.
- **Legal —** To avoid encroaching on property lines and to establish a standard against which the work can be compared.
- **Contractual —** To establish an acceptability range and also to establish responsibility for developing and maintaining specified tolerances.

13.1.3 Responsibility

While the responsibility for specifying and maintaining tolerances of the various elements of construction may vary among projects, it is important that these responsibilities be clearly assigned. The conceptual design phase of a precast concrete project is the time to begin considering dimensional control. The established tolerances or required performance should fall within generally accepted industry ranges and should not be made more restrictive than necessary.

Once the tolerances have been specified, and connections that consider those tolerances have been designed, the production and erection of the components must be organized to ensure tolerance compliance.

A quality control program that emphasizes dimensional control is necessary. Likewise, an erection quality assurance program that includes a clear definition of responsibilities will aid in ensuring that the products are assembled in accordance with the specified erection tolerances.

Responsibility should include dimension verification and adjustment, if necessary, of both precast concrete components and any interfacing structural elements.

13.1.4 Tolerance Acceptability Range

Tolerances must be used as guidelines for acceptability and not as limits for rejection. If specified tolerances are met, the product should be accepted. If not, the product may be accepted if it meets any of the following criteria:

- Exceeding the tolerance does not affect the structural integrity or architectural performance of the component.
- The component can be brought within tolerance by structurally and architecturally satisfactory means.
- The total erected assembly can be modified to meet all structural and architectural requirements.

13.1.5 Relationships between Different Tolerances

A precast concrete component is erected so that its primary control surface is in conformance with the established erection and interfacing tolerances. The secondary control surfaces are generally not directly positioned during erection but are controlled by the product tolerances. Thus, if the primary control surfaces are within erection and interfacing tolerances, and the secondary surfaces are within product tolerances, the component is erected within tolerance. The resulting tolerance limit for the secondary surface may be the sum of the product and erection tolerances.

Because tolerances for some features of a precast concrete component may be additive, it must be clear to the erector which are the primary control surfaces. If both primary and secondary control surfaces must be controlled, provisions for adjustment should be included. The accumulated tolerance limits may have to be accommodated in the interface clearance. Surface and feature control requirements should be clearly outlined in the plans and specifications.

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On occasion, the structure may not perform properly if the tolerances are allowed to accumulate. Which tolerance takes precedence is a question of economics. The costs associated with each of the three tolerances must be evaluated, recognizing unusual situations. This may include difficult erection requirements, connections that are tolerance-sensitive, or production requirements that are set by the available equipment. Any special tolerance requirements should be clearly noted in the contract documents.

It is important for the designer of record to be aware of and take into consideration the tolerances of other building materials and systems used in the project.[5, 6, 7]

13.2 Product Tolerances

13.2.1 General

Product tolerances are listed in the primary report of the PCI Committee on Tolerances, *Tolerance Manual for Precast and Prestressed Concrete Construction,* MNL-135-00.[1] This report contains a more complete discussion of tolerances and should be referred to for more specific details, such as location tolerances for inserts, voids, haunches, and corbels, and for warping tolerances and local smoothness requirements. Tolerances are also presented more completely in three PCI publications, *Manual for Quality Control for Plants and Production of Structural Precast Concrete Products,* MNL-116-99; *Manual for Quality Control for Plants and Production of Architectural Precast Concrete Products,* MNL-117-96; and *Erectors' Manual: Standards and Guidelines for the Erection of Precast Concrete Products,* MNL-127-99.[2,3,4] The products included are listed in Table 13.2.1 in this handbook. Discussion of the more critical tolerances are given in following sections. The values shown have become the consensus standards of the precast concrete industry, and these values are occasionally different from tolerances published by other organizations.[6] More restrictive tolerances may significantly increase costs; they should not be specified unless absolutely necessary.

13.2.2 Overall Dimensions

Typical tolerances for most precast/prestressed concrete products are given in Table 13.2.1. Architectural precast concrete panels have plan dimension tolerances that vary with panel size from ± $^1/_8$ in. for a dimension under 10 ft to ± $^1/_4$ in. for a dimension of 20 ft to 40 ft. The thickness tolerance for top and bottom slabs (flanges) of box beams and hollow-core units are dependent on the position of cores. Flange thickness tolerances are not given for hollow-core units. Instead, measured flange areas cannot be less than 85% of the nominal calculated area.

MNL-135-00 emphasizes that the recommended tolerances are only guidelines. Different values may be applicable in some cases, and each project should be considered individually. The designer should also make reference to applicable building codes to establish possibly different tolerances for certain products. For example, Section 1009.3.2 of *International Building Code 2006*[8] requires that "the tolerance between the largest and smallest riser height or between the largest and smallest tread depth shall not exceed 0.375 in. in any flight of stairs." Other similar situations may exist.

13.2.3 Sweep or Horizontal Misalignment

Horizontal misalignment, or sweep, usually occurs as a result of form and component width tolerances. It can also result from prestressing with lateral eccentricity, which should be considered in the design. Joints should be dimensioned to accommodate such variations.

Sweep tolerances generally vary with the length of a unit, for example, ± $^1/_8$ in. per 10 ft. The upper limit of sweep varies from ± $^3/_8$ in. for wall panels and hollow-core units to ± $^3/_4$ in. for joists usually used in composite construction.

13.2.4 Position of Strands

It is a common practice to use $^5/_8$ in.-diameter holes in end dividers (bulkheads or headers) for $^3/_8$, $^7/_{16}$, $^1/_2$, and 0.6-in.-diameter strands, because it is costly to switch end dividers for different strand diameters. Therefore, better accuracy in strand placement is achieved when using larger diameter strands.

Generally, individual strands must be positioned within ± $^1/_4$ in. of design position and bundled strands within ± $^1/_2$ in. Hollow-core units have greater individual strand tolerances as long as the center of gravity of the strand group is within ± $^1/_4$ in. and a minimum cover of $^3/_4$ in. is maintained.

13.2.5 Camber and Differential Camber

Predicted camber is generally based on camber at release of prestress; therefore, camber measurements on products should be made as soon after stripping from the forms as possible. Differential camber refers to the final in-place condition of adjacent components.

It is important that cambers are measured at the same time of day, preferably in the early hours before the sun has warmed the components. Cambers for all units used in the same assembly should be checked at the same age. If a significant deviation in camber from calculated values is observed, the cause should be determined and the effect of the deviation on the performance of the component should be evaluated. It should be understood that calculations predicting camber are approximate and that the normal variations of the parameters used can cause deviations of ± 20% over predicted camber.

The final installed differential displacement between two adjacent cambered components erected in the field may be the combined result of component differential cambers, variations in support elevations, variation in component depth, and any adjustments made to the components during erection. If differential cambers exceed recommended tolerances, additional effort is often required to erect the components in a manner that is satisfactory for the intended use.

For most flexural components, the tolerance for maximum camber variation from predicted camber is ± $^3/_4$ in., and maximum differential camber between adjacent units of the same design is $^3/_4$ in. This may be increased for joists that are used in composite construction. Pretopped precast concrete double-tees in parking structures should have a more stringent tolerance for differential camber between adjacent double-tees so that a smooth riding surface is achieved. A $^1/_4$ in. differential is recommended in Reference 9. Recommendations for camber and differential camber of hollow-core units are not listed because production variations between hollow-core systems result in different tolerances for each type. Regional precast concrete manufactureres should be consulted for appropriate tolerances if differential hollow-core unit camber tolerances are important for a particular project application.

13.2.6 Weld Plates

In general, it is easier to hold plates to closer tolerances at the bottom of a component (as cast or against the side form) than with plates cast in the top of the component. Bottom and side plates can be fastened to the form and, hence, are less susceptible to movement caused by vibration. This applies to position of weld plates as well as tipping and flushness.

The tolerance on weld plates is less restrictive than for bearing plates. The position tolerance is ± 1 in. for all products. Tipping and flushness tolerance is ± $^1/_4$ in.

13.2.7 Haunches of Columns and Wall Panels

The importance of corbel- or haunch-location tolerances depends on the connection at the base of the component. Because base connections usually allow some adjustability, it is more important to control dimensions from haunch to haunch in multilevel columns or walls than from haunch to the base of the component.

The haunch-to-haunch tolerance is ± $^1/_8$ in. to ± $^1/_4$ in. Bearing surface squareness tolerance is ± $^1/_8$ in. per 18 in. with a maximum of ± $^1/_4$ in., except for architectural precast concrete panels, which have a tolerance of ± $^1/_8$ in., and columns, which have a maximum tolerance of ± $^1/_8$ in. in the short direction and ± $^3/_8$ in. in the long direction.

Table 13.2.1 Typical tolerances for precast/prestressed concrete components

Product tolerances	Products
Length	
± $^1/_4$ in.	18
± $^3/_8$ in.	16, 17
± $^1/_2$ in.	6, 7, 8, 9, 13, 15
± $^3/_4$ in.	3, 5
± 1 in.	1, 2, 4, 11, 12, 14
Width	
± $^1/_4$ in.	1, 2, 3, 5, 6, 7, 8, 9, 12, 15, 16, 18
+ $^3/_8$ in.	14
+ $^3/_8$ in., – $^1/_4$ in.	4
± $^3/_8$ in.	11, 13
± $^1/_2$ in.	17
Depth	
+ $^1/_4$ in., – $^1/_8$ in.	10,18
± $^1/_4$ in.	1, 2, 3, 5, 6, 7, 8, 9, 12, 13, 14, 15
+ $^1/_2$ in., – $^1/_4$ in.	4
± $^3/_8$ in.	11
Flange thickness	
+ $^1/_4$ in., –$^1/_8$ in.	1, 2, 8, 10, 12, 15
± $^1/_4$ in.	3, 4
Web thickness	
± $^1/_8$ in.	1, 8, 10, 12, 15
± $^1/_4$ in.	2,3
+ $^3/_8$ in., –$^1/_4$ in.	4
± $^3/_8$ in.	5
Position of tendons	
± $^1/_4$ in.	1, 2, 3, 4, 5, 6, 8, 9, 11, 12, 14, 15, 18
± $^1/_4$ in. thickness, ± 1 in. width	10
Camber, variation from design	
± $^1/_4$ in. per 10 ft, ± $^3/_4$ in. maximum	1, 2, 12, 15
± $^1/_8$ in. per 10 ft, ± 1 in. maximum	4
± $^3/_4$ in. maximum	3
± $^1/_2$ in. maximum	5, 15
Camber, differential	
$^1/_4$ in. per 10 ft, $^3/_4$ in. maximum	1, 2, 5
± $^1/_4$ in. per 10 ft, ± $^1/_2$ in. maximum	15
Bearing plates, position	
± $^1/_2$ in.	1, 2, 3, 12, 15
± $^5/_8$ in.	4
Bearing plates, tipping and flushness	
± $^1/_8$ in.	1, 2, 3, 4, 12, 13, 15
Key: 1 = double-tee 2 = single-tee 3 = building beam (rectangular and ledger) 4 = I-beam 5 = box beam 6 = column 7 = hollow-core unit 8 = ribbed wall panel 9 = insulated wall panel	10 = architectural wall panel 11 = pile 12 = joist 13 = step unit (see section 13.2.2) 14 = sheet piling 15 = stadium riser unit 16 = prison cell module – single 17 = prison cell module – double 18 = prestressed concrete panels for storage tanks

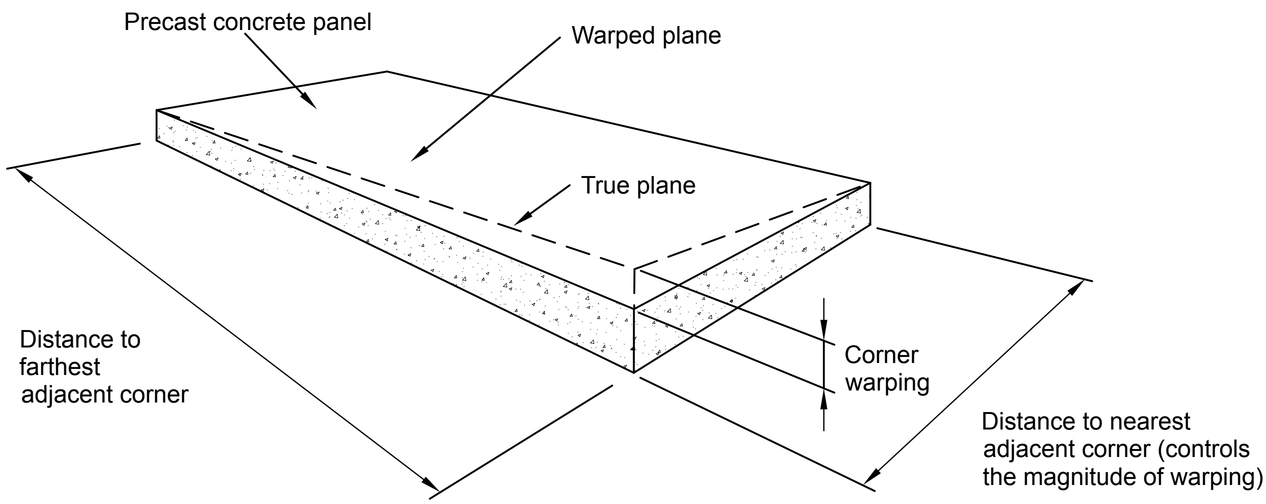


Fig. 13.2.1 Definition of panel warping.

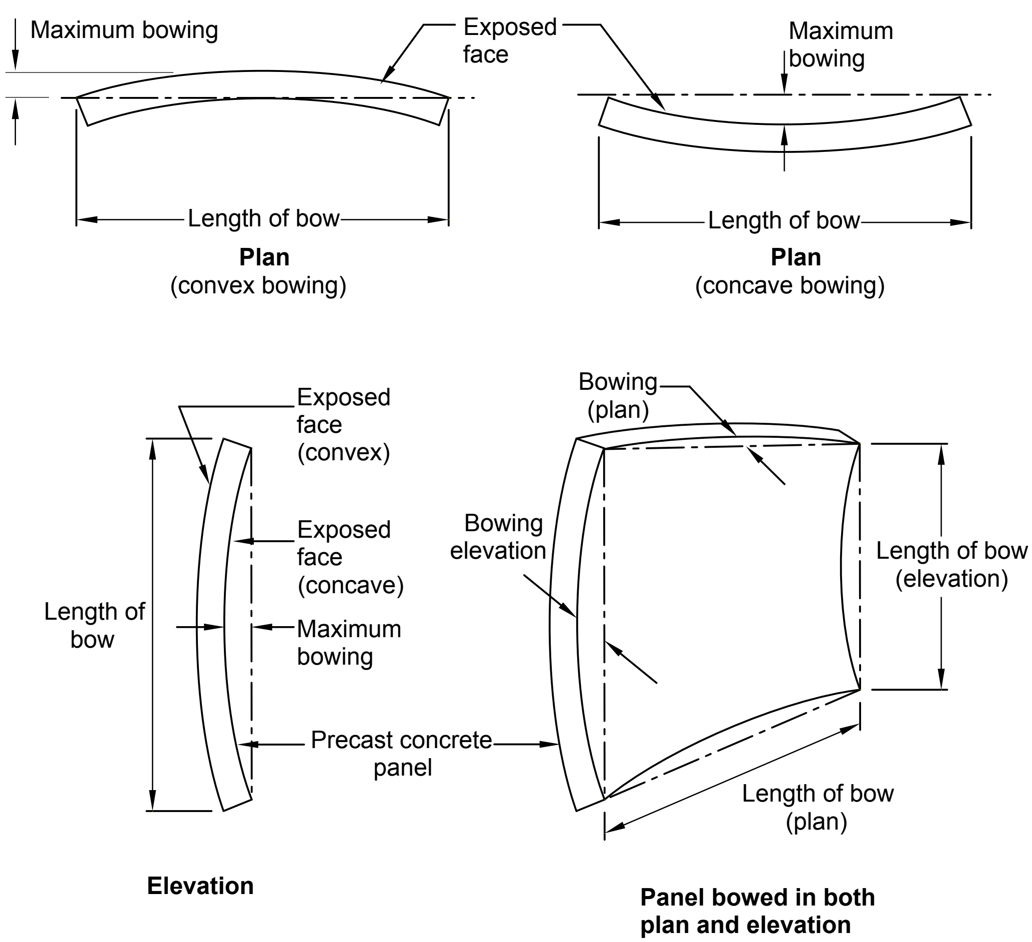


Fig. 13.2.2 Definition of panel bowing.

13.2.8 Warping and Bowing

Warping and bowing tolerances affect panel-edge matchup during erection and the appearance of the erected components. These tolerances are especially critical with architectural precast concrete panels. Warping is a deviation from plane in which the corners of the panel do not fall within the same plane. Warping tolerances are given in terms of corner deviations (Fig. 13.2.1). The allowable deviation from the nearest adjacent corner is $^1/_{16}$ in. per ft.

Bowing differs from warping in that two opposite edges of a panel may fall in the same plane, but the portion of the panel between the edges is out of plane (Fig. 13.2.2). Bowing tolerance is $L/360$, where L is the length of panel. Maximum tolerance on differential bowing between panels of the same design is $^1/_2$ in.

The effects of differential temperature and moisture absorption between the inside and outside of a panel and the prestress eccentricity should be considered in design of the panel and its connections. Pre-erection storage conditions may also affect warping and bowing (see Sections 5.8.5 and 8.4.2).

Thin panels are more likely to bow than thick panels, and the tolerances for thinner panels should be more liberal. Similarly, panels made from concrete with a maximum aggregate size greater than $^3/_4$ in., panels using two significantly different concretes, and veneered and insulated panels may require special consideration. In all cases, the regional precaster should be consulted regarding overall economic and construction feasibility.

13.2.9 Smoothness

Local smoothness describes the condition where small areas of the surface may be out-of-plane (Fig. 13.2.3). The tolerance for this type of variation is $^1/_4$ in. per 10 ft for all products. The tolerance is usually checked with a 10 ft straight edge or the equivalent, as explained in Fig. 13.2.3.

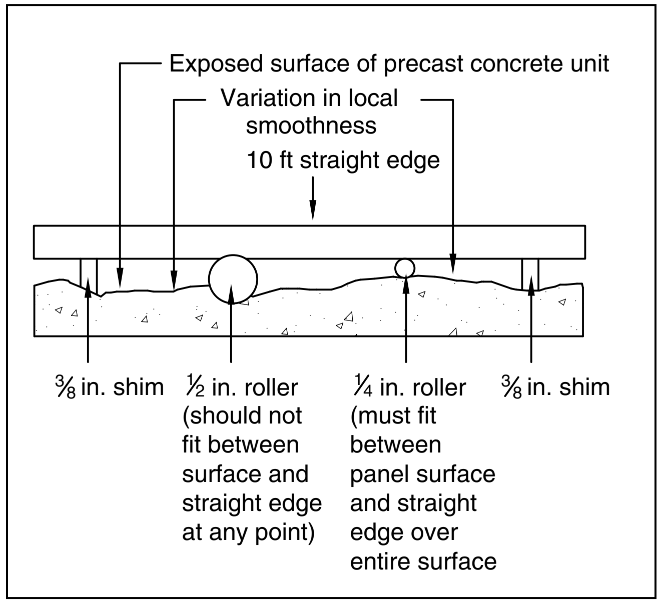


Fig. 13.2.3 Local smoothness variation.

13.2.10 Architectural Panels versus Structural Products

When discussing tolerances, an architectural panel refers to a class of specified tolerances, not necessarily to the use of the component in the final structure. Architectural panels usually require more restrictive tolerances than structural components for aesthetic reasons. These types of panels are produced in PCI-Certified plants that have an A1 certification. Structural products such as load-bearing spandrel panels, insulated sandwich panels, double-tees, hollow-core units, and solid slabs are often used for exterior facades but are not considered architectural panels. Because of the production method used, structural products with an applied architectural finish have the same tolerance requirements that they would have if they were made without an aesthetic finish. Many structural products are larger than typical architectural panels and require the larger tolerances given in MNL-116-99. Also, structural panels with architectural finishes often carry substantial loads, as in the case of a spandrel panel of a parking garage. These type of panels need to have the larger tolerances specified for structural panels because they are produced by the same people, using the same type of formwork as plain, gray structural panels. Structural panels with an architectural finish are made in PCI-Certified plants that have a C-A certification. If more restrictive tolerances are required, they must be clearly indicated in the contract documents, and the subsequent increased costs should be considered.

13.3 Erection Tolerances

13.3.1 General

Erection tolerances are those to which the primary control surfaces of the component should be set. The final location of other features and surfaces will be the result of the combination of the the erection tolerances given in this section and the product tolerances given in Section 13.2. Table 13.3.1 lists erection tolerances for interface design of precast and cast-in-place concrete components. Table 13.3.2 lists recommended clearances.

Because erection depends on the equipment used and site, there may be good reasons to vary some of the recommended tolerances to account for unique project conditions. In general, the more restrictive the erection tolerances are, the higher the cost of erection will be. To minimize erection problems, the dimensions of the in-place structure should be checked prior to starting erection. After erection, and before other trades interface with the precast concrete components, it should be verified that the precast concrete components are erected within tolerances.[6]

Table 13.3.1 Erection tolerances for interface design of precast and cast-in-place concrete components

Item	Recommended tolerances
Variation in plan location (any column or beam, any location)	± 1/2 in. for columns, ± 1 in. for beams
Variation in plan parallel to specified building lines	+ 1/40 in. per ft for any beam less than 20 ft long or adjacent to columns spaced less than 20 ft apart 1/2 in. maximum for adjacent columns spaced 20 ft or more apart
Difference in relative position of adjacent columns from specified relative position (at any check level)	+ 1/2 in.
Variation from plumb	+ 1/4 in. for any 10 ft of height 1 in. maximum for the entire height
Variation in elevation of bearing surfaces from specified elevation (any column or beam, any location)	Maximum low = 1/2 in. Maximum high = 1/4 in.
Variation of top of spandrel from specified elevation (any location)	+ 1/2 in.
Variation in elevation of bearing surfaces from lines parallel to specified grade lines	+ 1/40 in. per ft for any beam less than 20 ft long or for adjacent columns spaced less than 20 ft apart 1/2 in. maximum for any beam 20 ft or more in length or for adjacent columns spaced 20 ft or more apart
Variation from specified bearing length on support	± 3/4 in.
Variation from specified bearing width on support	± 1/2 in.
Jog in alignment of matching edges	1/2 in. maximum

Table 13.3.2 Recommended clearances

Item	Recommended minimum clearance
Precast concrete component to precast concrete component	1/2 in. (1 in. preferred)
Precast concrete component to cast-in-place concrete	1 in. (2 in. preferred)
Precast concrete component to steel	1 in. (2 in. preferred)
Precast concrete column covers	1 1/2 in. (3 in. preferred for tall buildings)

13.3.2 Recommended Erection Tolerances

Figures 13.3.2 through 13.3.9 show erection tolerances for the following four mixed building systems:

- precast concrete component to precast concrete component
- precast concrete component to cast-in-place concrete
- precast concrete component to masonry
- precast concrete component to structural steel construction

See Reference 4 for recommended erection tolerances for additional precast concrete components.

The tolerances outlined in this section should be the specified tolerances for erection of precast concrete components. If tolerances are desired that are different from those published in PCI documents, this should be made very clear to bidders in the bid documents.

13.3.3 Mixed Building Systems

Mixed building systems combine precast and prestressed concrete with other materials, usually cast-in-place concrete, masonry, or steel. Typically each industry has its own recommended erection tolerances that apply when its products are used exclusively. The compatibility of those tolerances

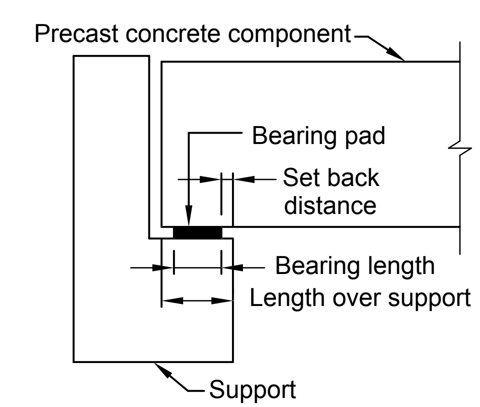


Fig. 13.3.1 Relationship between bearing length and length over support.

with the precast concrete tolerances should be checked and adjusted when necessary.

Example 13.4.2 presents a problem that can occur when erection tolerances are chosen for each system without considering the project as a whole.

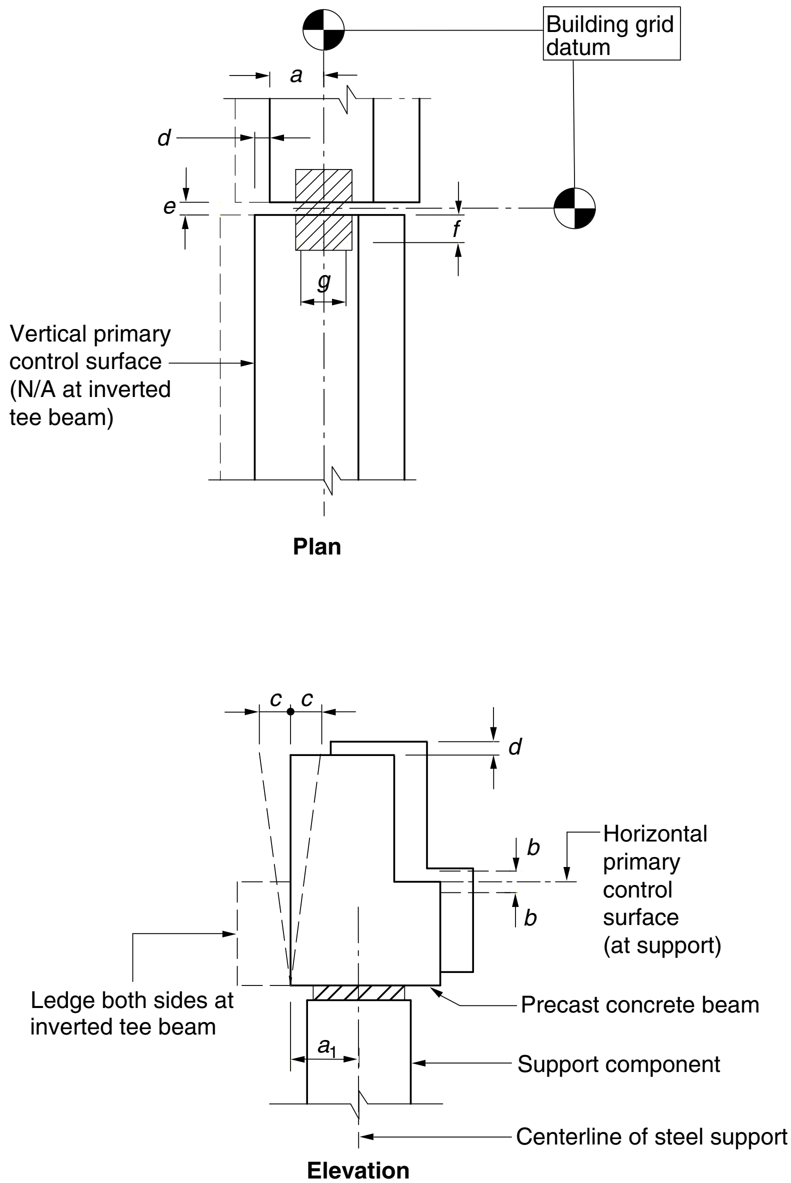
13.3.4 Connections and Bearing

The details of connections must be considered when specifying erection tolerances. Space must be provided to perform the tasks necessary to complete the connection under the most adverse combination of tolerances.

Bearing length is measured in the direction of the span, and bearing width is measured perpendicular to the span. Bearing length is often not the same as the length of the component's end projecting over the support (Fig. 13.3.1). When they differ, it should be noted on the erection drawings.

The engineer may wish to specify a minimum bearing (size, length, and width) for various precast concrete products. For additional information, see Reference 6.

Fig 13.3.2 Beam erection tolerances



Precast concrete component to precast concrete component, cast-in-place concrete, masonry, or structural steel

Fig. 13.3.2 Beam erection tolerances (cont.)

The primary control surfaces for beam erection tolerances are usually as shown, although this needs to be confirmed on a job-by-job basis.

a = Plan location from building grid datum .... ± 1 in.

a_1 = Plan location from centerline of steel[a] .... ± 1 in.

b = Bearing elevation[b] from nominal elevation at support:
- Maximum low .... $^1/_2$ in.
- Maximum high .... $^1/_4$ in.

c = Maximum plumb variation over height of component:
- Per 12 in. height .... $^1/_8$ in.
- Maximum at rectangular or L-beam .... $^1/_2$ in.
- Maximum at inverted-tee beam .... $^3/_4$ in.

d = Maximum jog in alignment of matching edges:
- Architectural exposed edges .... $^1/_4$ in.
- Visually non-critical edges .... $^1/_2$ in.

e = Joint width:
- Architectural exposed joints .... ± $^1/_4$ in.
- Hidden joints .... ± $^3/_4$ in.
- Exposed structural joint not visually critical .... ± $^1/_2$ in.

f = Bearing length[c] (span direction) .... ± $^3/_4$ in.

g = Bearing width[c] .... ± $^1/_2$ in.

Note: When bearing pads are used at unarmored edges, they should be set back a minimum of $^1/_2$ in. from the face of the support or at least the chamfered dimension at chamfered edges.

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a. For precast concrete components on a steel frame, this tolerance takes precedence over tolerance on dimension *a*.

b. Or component top elevation where component is part of a frame without bearing ledges.

c. This is a setting tolerance and should not be confused with structural performance requirements set by the architect/engineer. The nominal bearing dimensions and the allowable variations in the bearing length and width should be specified by the engineer and shown on the erection drawings.

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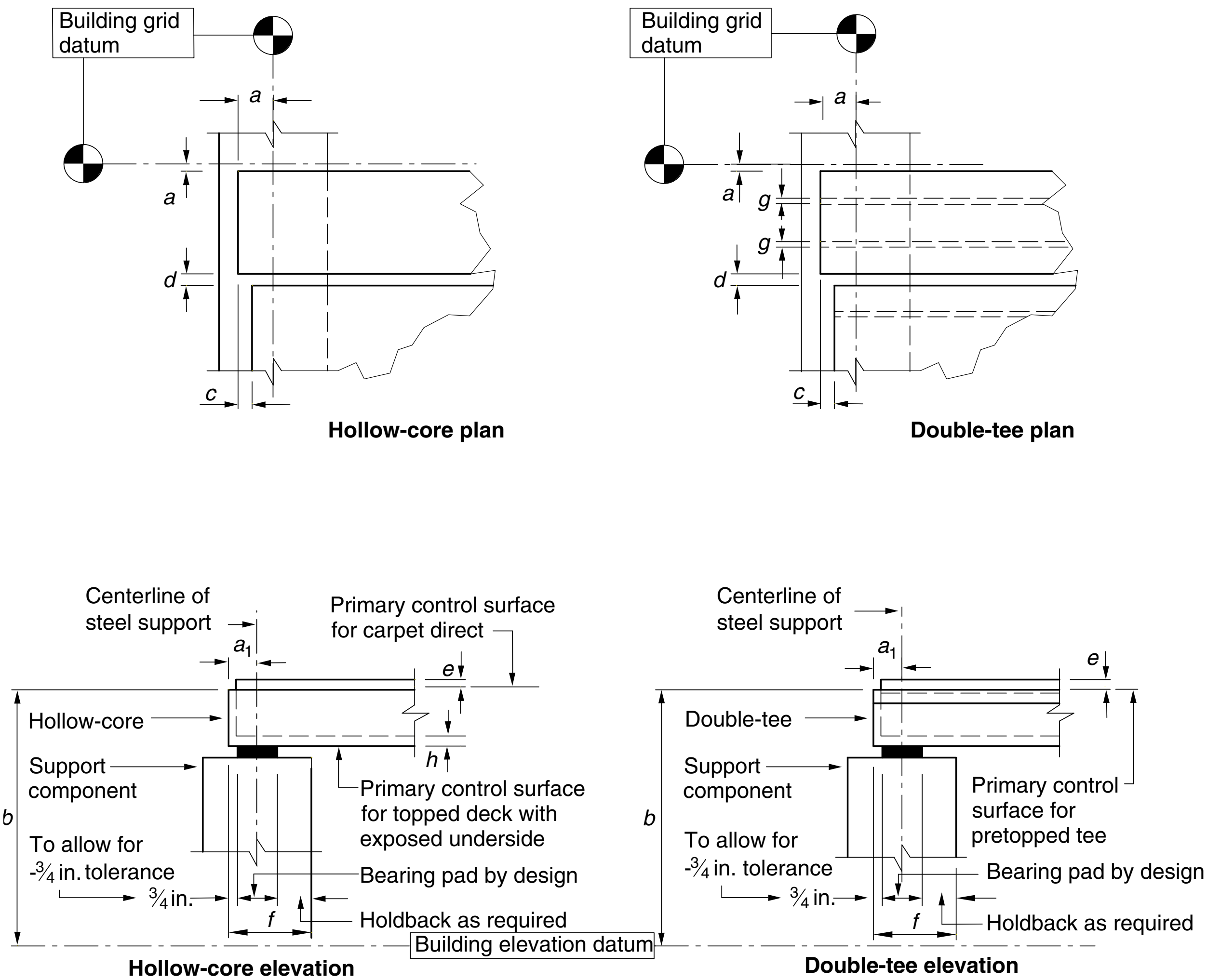
Fig. 13.3.3 Floor and roof component erection tolerances



Precast concrete component to precast, cast-in-place concrete, masonry or structural steel support

Fig. 13.3.3 Floor and roof component erection tolerances (cont.)

The primary control surfaces for floor and roof component erection tolerances are usually as shown. Tyipcally, there is no designated vertical, primary control surface, and in some scenarios, there are no primary control surfaces at all. This needs to be determined on a job-by-job basis.

a = Plan location from building grid datum .... ± 1 in.

a_1 = Plan location from centerline of steel support[a] .... ± 1 in.

b = Top elevation from building elevation datum at component ends:
Covered with topping .... ± 3/4 in.
Pretopped tee/carpet direct hollow-core unit .... ± 1/4 in.
Untopped roof .... ± 3/4 in.

c = Maximum jog in alignment of matching edges
(both topped and untopped construction) .... 1 in.

d = Joint width:
0 ft to 40 ft component .... ± 1/2 in.
41 ft to 60 ft component .... ± 3/4 in.
61 ft + component .... ± 1 in.

e = Differential top elevation as erected (for units of same design and length):
Field topped .... 3/4 in.
Pretopped tees at driving lanes .... 1/4 in.
Carpet direct hollow-core slabs .... 1/4 in.
Untopped roof[b] .... 3/4 in.

f = Bearing length[c] (span direction) .... ± 3/4 in.

g = Bearing width[c] (not applicable for hollow-core slabs) .... ± 1/2 in.

h = Differential bottom elevation of exposed hollow-core slabs[d] .... 1/4 in.

Note: When bearing pads are used at unarmored edges they should be set back a minimum of 1/2 in. from the face of the support or from at least the chamfered dimension at chamfered edges.

---

a. For precast concrete erected on a steel frame building, this tolerance takes precedence over tolerance on dimension *a*.

b. It may be necessary to feather the edges to ± 1/4 in. to properly apply some roof membranes.

c. This is a setting tolerance and should not be confused with structural performance requirements set by the architect/engineer. The nominal bearing dimensions and the allowable variations in the bearing length and width should be specified by the engineer and shown on the erection drawings.

d. Untopped installations will require a larger tolerance.

Fig. 13.3.4 Column erection tolerances

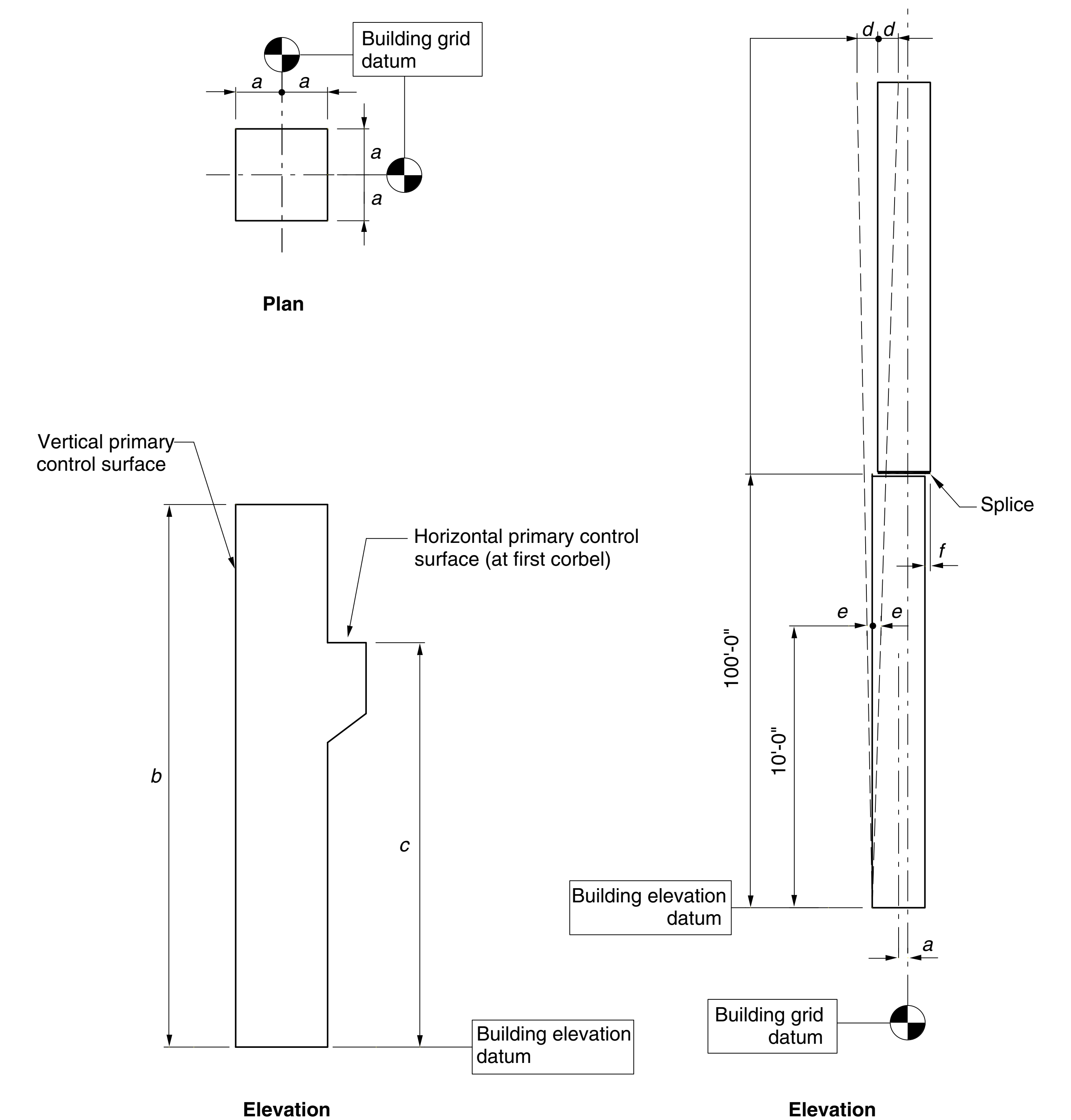


Fig 13.3.4 Column erection tolerances (cont.)

The primary control surfaces are usually as shown, although this needs to be confirmed on a job-by-job basis.

a = Plan location from building grid datum:
- Structural applications .... ± 1/2 in.
- Architectural applications .... ± 3/8 in.

b = Top elevation from nominal top elevation:
- Maximum low .... 1/2 in.
- Maximum high .... 1/4 in.

c = Bearing haunch elevation from nominal elevation:
- Maximum low .... 1/2 in.
- Maximum high .... 1/4 in.

d = Maximum plumb variation over height of component (component in structure of maximum height of 100 ft): .... 1 in.

e = Plumb in any 10 ft of element height .... 1/4 in.

f = Maximum jog in alignment of matching edges:
- Architectural exposed edges .... 1/4 in.
- Visually non-critical edges .... 1/2 in.

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Fig. 13.3.5 Structural wall panel erection tolerances

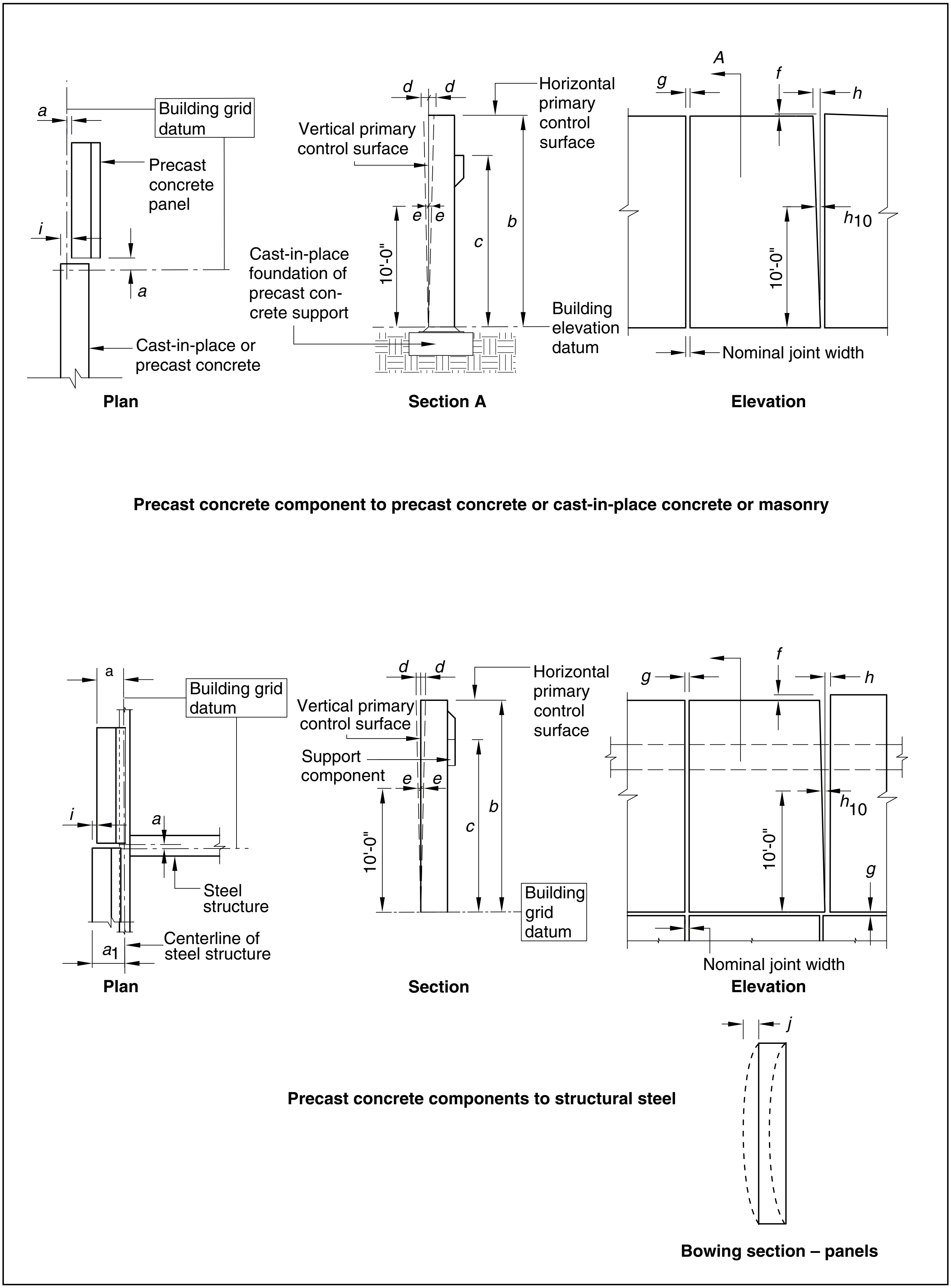

Fig. 13.3.5 Structural wall panel erection tolerances (cont.)

The primary control surfaces are usually as shown, although this needs to be confirmed on a job-by-job basis.

a = Plan location from building grid datum[a] .... ± $^1/_2$ in.

a_1 = Plan location from centerline of steel support .... ± $^1/_2$ in.

b = Top elevation from nominal top elevation:
- Exposed individual panel .... ± $^1/_2$ in.
- Non-exposed individual panel .... ± $^3/_4$ in.
- Exposed relative to adjacent panel .... ± $^1/_2$ in.
- Non-exposed relative to adjacent panel .... ± $^3/_4$ in.

c = Support elevation from nominal elevation:
- Maximum low .... $^1/_2$ in.
- Maximum high .... $^1/_4$ in.

d = Maximum plumb variation over height of structure or over 100 ft, which ever is less[a] .... 1 in.

e = Plumb in any 10 ft of element height .... $^1/_4$ in.

f = Maximum jog in alignment of matching edges .... $^1/_2$ in.

g = Joint width (governs over joint taper) .... ± $^3/_8$ in.

h = Joint taper over height of panel .... $^1/_2$ in.

h_{10} = Joint taper over 10 ft height .... $^3/_8$ in.

i = Maximum jog in alignment of matching faces:
- Exposed to view .... $^3/_8$ in.
- Not exposed to view .... $^3/_4$ in.

j = Differential bowing as erected between adjacent components of the same design[b] .... $^1/_2$ in.

---

a. For precast concrete buildings in excess of 100 ft tall, tolerances *a* and *d* can increase at the rate of $^1/_8$ in. per story to a maximum of 2 in.

b. Refer to Section 13.2.8 for description of bowing tolerance.

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Fig. 13.3.6 Architectural walls/spandrel erection tolerances

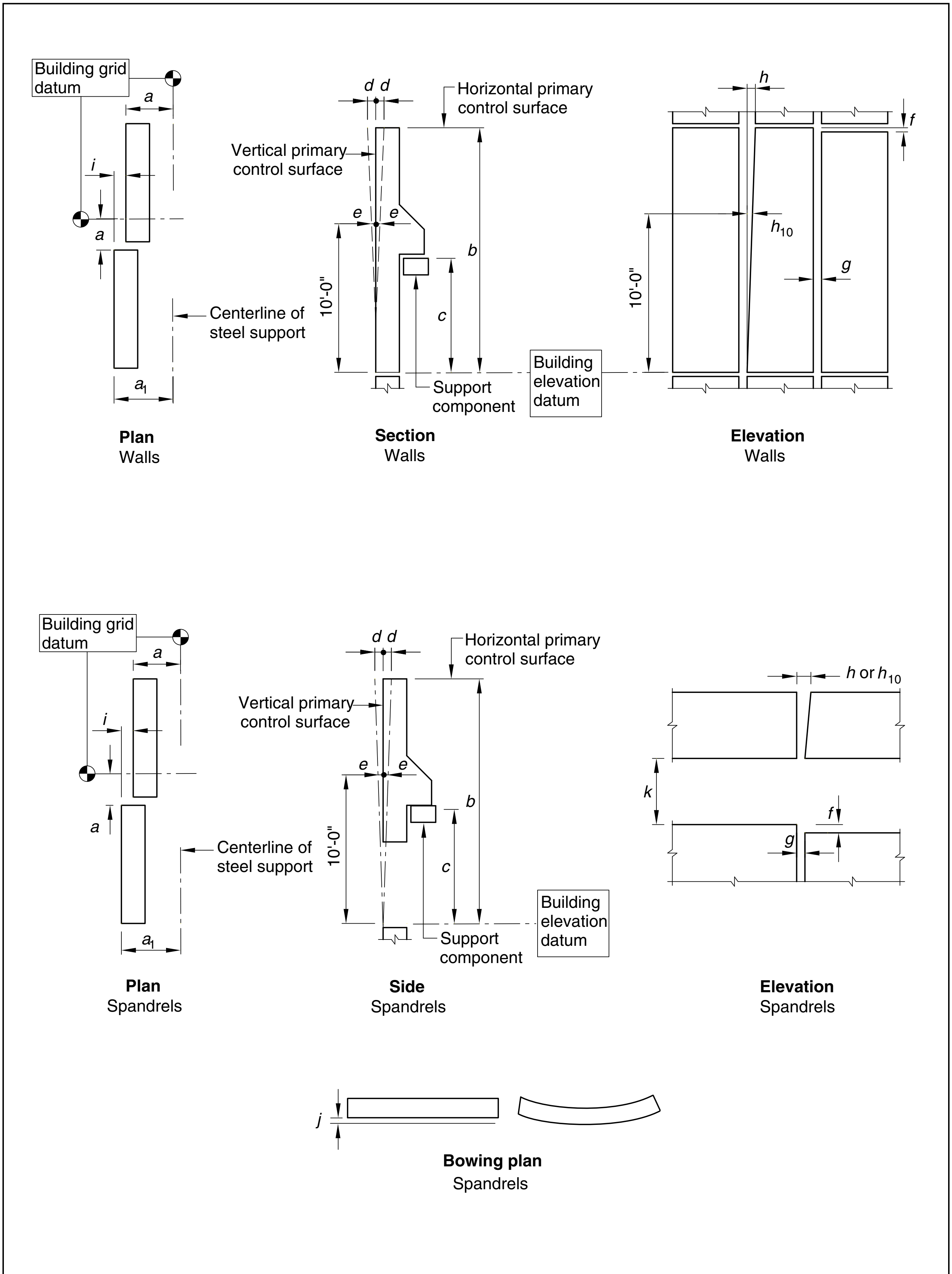

Fig. 13.3.6 Architectural walls/spandrel erection tolerances (cont.)

The primary control surfaces are usually as shown, although this needs to be confirmed on a job-by-job basis.

a = Plan location from building grid datum[a] .... ± 1/2 in.

a_1 = Plan location from centerline of steel support[b] .... ± 1/2 in.

b = Top elevation from nominal top elevation:
- Exposed individual panel .... ± 1/4 in.
- Non-exposed individual panel .... ± 1/2 in.

c = Support elevation from nominal elevation:
- Maximum low .... 1/2 in.
- Maximum high .... 1/4 in.

d = Maximum plumb variation over height of structure or 100 ft, whichever is less[a] .... 1 in.

e = Plumb in any 10 ft of element height .... 1/4 in.

f = Maximum jog in alignment of matching edges:
- Exposed relative to adjacent panel .... 1/4 in.
- Non-exposed relative to adjacent panel .... 1/2 in.

g = Joint width (governs over joint taper) .... ± 1/4 in.

h = Joint taper maximum .... 3/8 in.

h_{10} = Joint taper over 10 ft length .... 1/4 in.

i = Maximum jog in alignment of matching faces .... 1/4 in.

j = Differential bowing as erected between adjacent components of the same design:
- Exposed relative to adjacent panel .... 1/4 in.
- Non-exposed relative to adjacent panel .... 1/2 in.

k = Opening height between spandrels .... ± 1/4 in.

---

a. For precast concrete buildings in excess of 100 ft tall, tolerances *a* and *d* can increase at the rate of 1/8 in. per story to a maximum of 2 in.

b. For precast concrete components erected on a steel frame, this tolerance takes precedence over tolerance on dimension *a*.

Fig. 13.3.7 Single, double, and triple riser erection tolerances

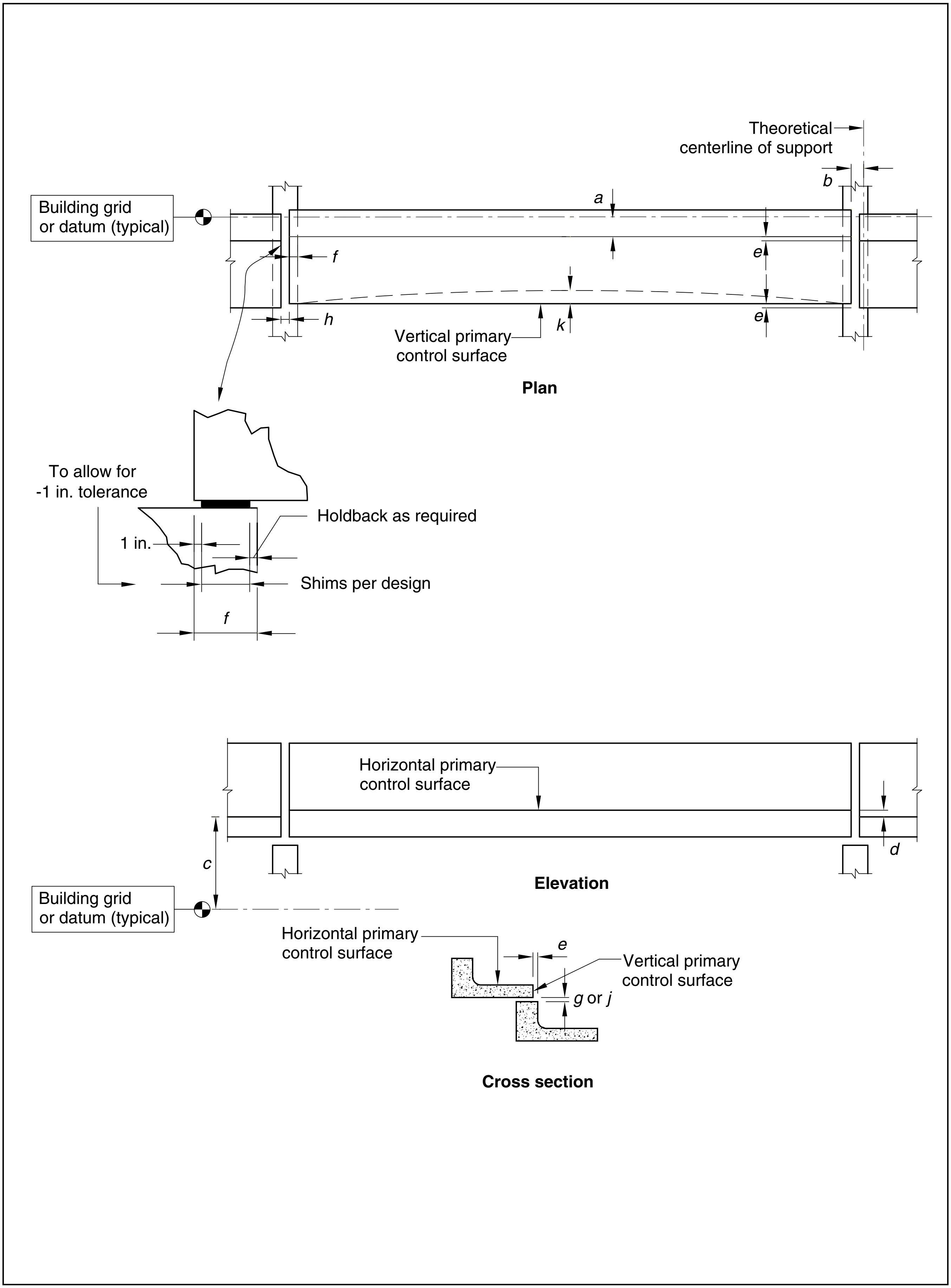

Fig. 13.3.7 Single, double, and triple riser erection tolerances (cont.)

The primary control surfaces for single, double, and triple riser erection tolerances are usually as shown, although this is something that needs to be confirmed with the contractor on a job-by-job basis. Local building codes may require more restrictive riser-height tolerances, which could also affect product tolerance.

a = Plan location from building grid line datum .... ± 1 in.

b = Plan location from theoretical centerline of support structure .... ± 1 in.

c = Top elevation from building elevation datum at member's end (datum may be adjusted to accommodate existing field conditions.) .... ± $^1/_2$ in.

d = Maximum jog in alignment of matching edges at the horizontal primary control surface .... $^1/_4$ in.

e = Maximum jog in alignment of matching edges at the vertical primary control surface .... $^1/_2$ in.

f = Bearing in span direction .... –1 in.

g = Joint width (horizontal) at end of piece (joint width needs to be $^1/_4$ in. minimum) .... ± $^1/_2$ in.

h = Joint width (joint width needs to be $^1/_4$ in. minimum in either case)
90 deg angle .... ± $^1/_2$ in.
Joint width at skewed ends .... ± $^5/_8$ in.

j = Differential camber (at midspan as erected) between adjacent components of the same design .... ± $^3/_{16}$ in. per 10 ft of component length

k = Differential sweep (at midspan as erected) between adjacent components of the same design .... ± $^3/_{16}$ in. per 10 ft of component length

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Fig. 13.3.8 Room module erection tolerances

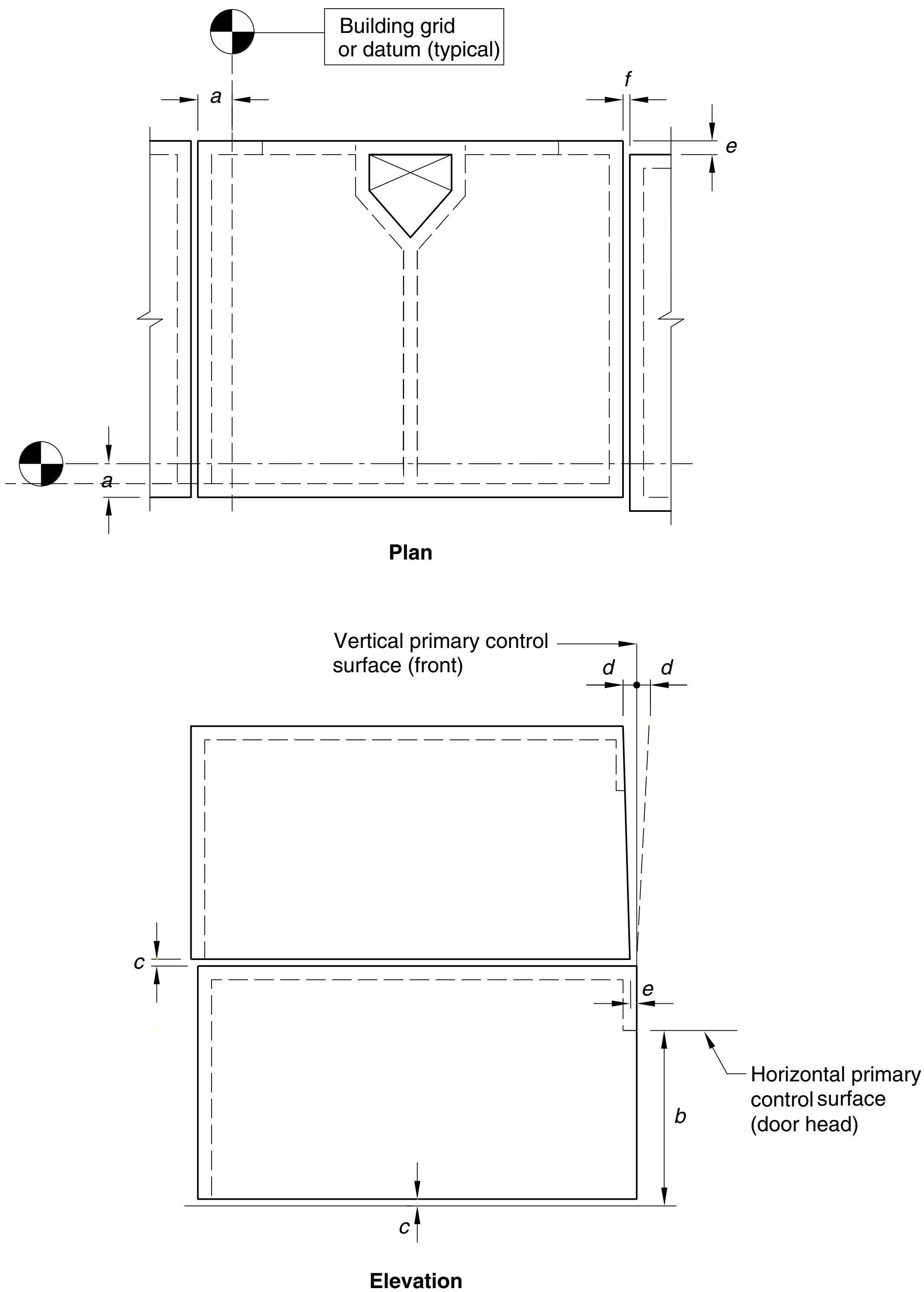

Fig. 13.3.8 Room module erection tolerances (cont.)

The tolerances listed below (*a–g*) are used at the primary control surfaces only, and only those tolerances that are applicable to that surface are used. Normally, the primary control surfaces are the front face of the room module as the vertical primary control surface, and either the head of the door, top of room module, or the bottom of balcony as the horizontal primary control surface.
Note: On jobs where pretopped balconies are cast as part of the room module, the horizontal primary control surface may be the top surface of the balcony.

a = Plan location from building grid line datum .... ± $^1/_2$ in.

b = Vertical control (at primary control surface) from a horizontal datum .... ± $^3/_8$ in.

c = Actual grout joint .... $^1/_2$ in. minimum

d = Plumb at element height .... $^1/_4$ in.

e = Maximum jog in alignment of matching edges .... $^1/_4$ in.

f = Vertical joint width .... ± $^3/_8$ in.

g = Joint taper .... Not applicable

Fig. 13.3.9 Stair unit erection tolerance

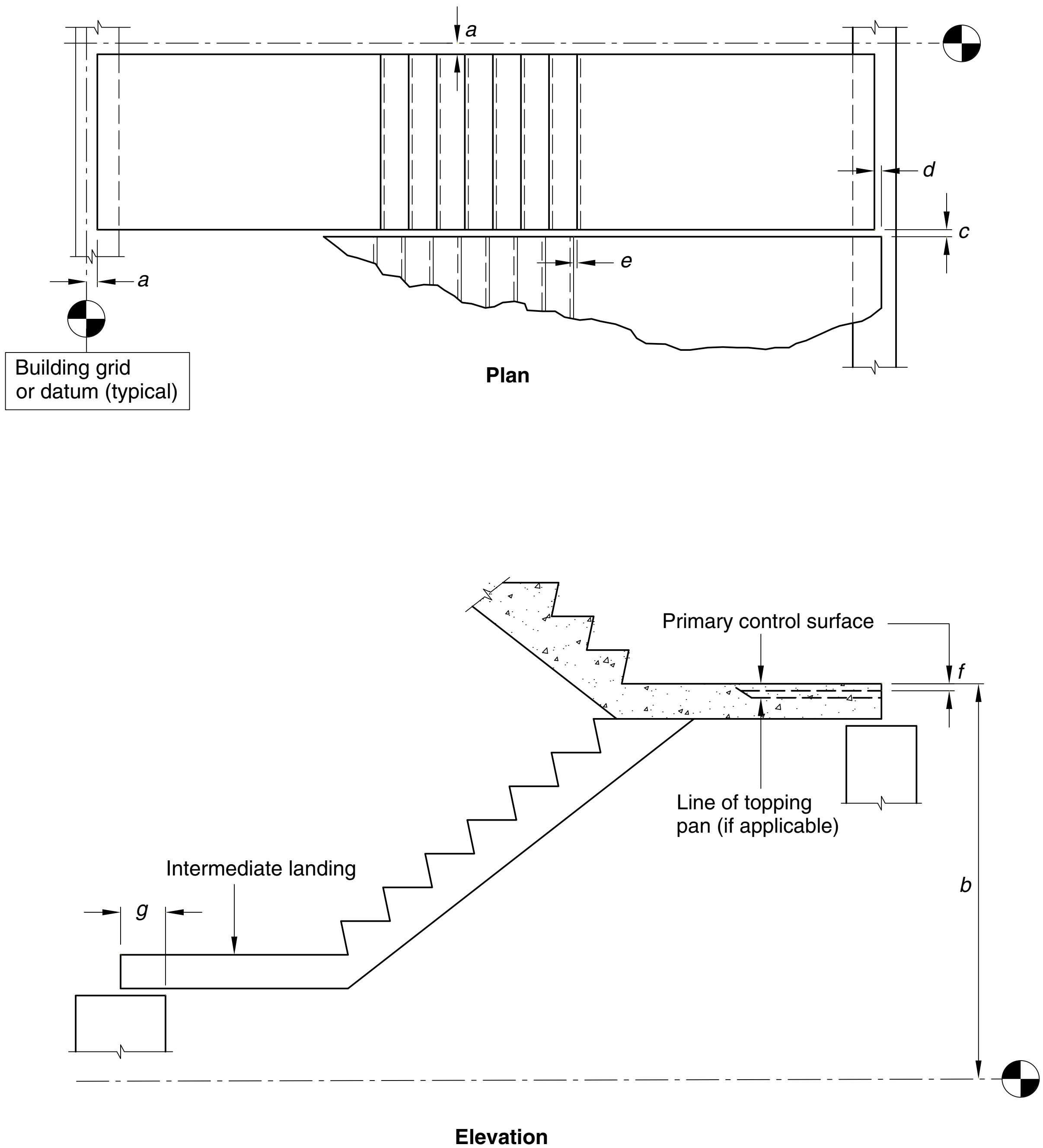

Fig. 13.3.9 Stair unit erection tolerance (cont.)

The primary control surface for stair units is the top of landing at floor levels. The tolerances listed here (*a*–*g*) are the same whether landings are monolithic or separate pieces. Local building codes may require more restrictive riser-height tolerance, which could also affect the product tolerance.

a = Plan location from building grid line datum .... ± 1/2 in.

b = Differential elevation as erected[a] .... ± 3/8 in.

c = Joint width .... ± 3/4 in.

d = Maximum jog in alignment of matching edges........ 1 in.

e = Maximum jog in alignment of stair tread nosings (tolerance overrides d if needed) .... 1/2 in.

f = Maximum jog in alignment of matching edges at the primary control surface[a] .... 3/8 in.

g = Bearing (in span direction) .... ± 3/4 in.

---

a. At stair units that have pretopped precast concrete landings, the maximum jog between stair units, as well as from stair unit to finish floor, cannot exceed 1/4 in. However, units that have landings that are topped have more leeway. This needs to be discussed and agreed on with the general contractor. See Section 13.2.2.

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13.4 Clearances

13.4.1 General

Clearance is the space between adjacent construction elements and provides a buffer area where erection and production tolerance deviations can be absorbed. The following items should be addressed when determining the appropriate clearance to provide in the design:

- product tolerance
- type of component
- size of component
- type of abutting construction
- location of component
- component movement
- function of component
- erection tolerance
- space required for fireproofing of steel
- thickness of plates, bolt heads, and other projecting elements

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Of these factors, product tolerances and component movement are the most significant. As shown in the following examples, it may not always be practical to account for all possible factors in the clearance provided. Table 13.3.2 provides recommended minimum clearances for various mixed building systems.

13.4.2 Joint Clearance

Joints between architectural panels must accommodate variations in the panel dimensions and erection tolerances for the panels. They must also provide a good visual line and be sufficiently wide to allow for proper joint-sealant installation. Generally, the larger the panels are, the wider the joints should be. For most situations, architectural panel joints should be designed as being not less than $^3/_4$ in. wide. Tolerances in overall building width and length are normally accommodated in panel joints.

13.4.3 Procedure for Determining Clearance

The following is a systematic approach for making a trial selection of a clearance value and then verifying that selection to ensure that it will allow practical erection to occur:

Step 1: Determine the maximum size of the components involved (basic or nominal dimension and additive tolerances). This should include not only the precast/prestressed concrete components, but also other materials.

Step 2: To the maximum component size, add the minimum space required for component movement resulting from deflection and thermal variations.

Step 3: Check if the resulting clearance allows the component to be erected within the erection and interfacing tolerances, such as plumbness, face alignment, and the like. Adjust the clearance as required to meet all the needs.

Step 4: Check if the component can physically be erected with this clearance. Consider the size and location of components in the structure and how connections will be made. Adjust the clearance as required.

Step 5: Review the clearance to see whether increasing its dimensions will allow easier, more economical erection without adversely affecting aesthetics. Adjust the clearance as required.

Step 6: Review structural considerations such as types of connections involved, sizes required, bearing area requirements, and other structural issues.

Step 7: Check design to ensure adequacy in the event that minimum component size should occur. Adjust clearance as required for minimum bearing and other structural considerations.

Step 8: Select final clearance that will satisfy all of the conditions considered.

13.4.4 Clearance Examples

The following examples are given to show the thought process, and may not be the only solutions for the situations that are described (Fig. 13.4.1 and 13.4.2).

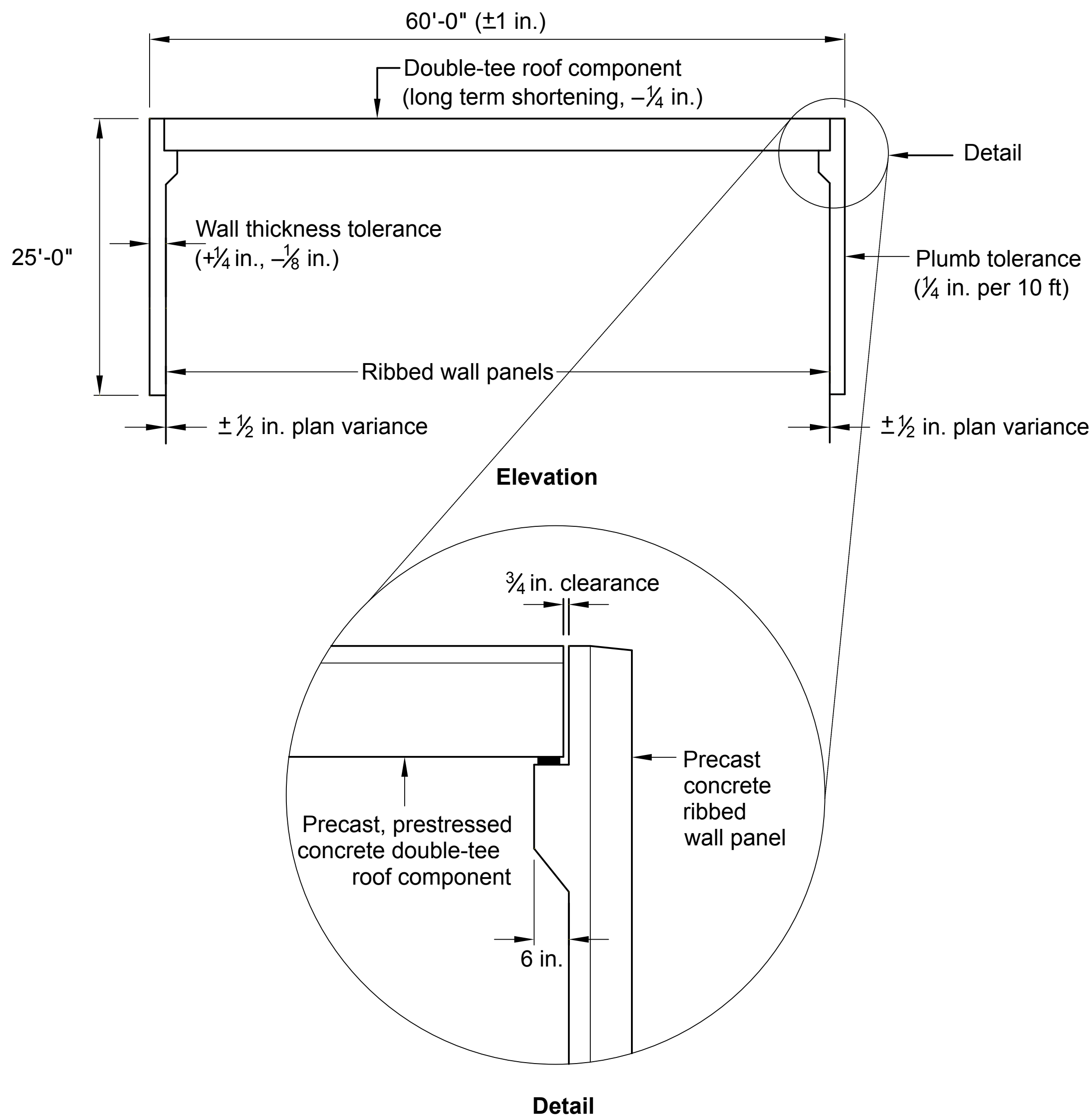

Fig. 13.4.1 Clearance example.

EXAMPLE 13.4.1

Clearance Determination – Single-Story Industrial Building

Given:

A 60-ft-long double-tee roof component is bearing on ribbed wall panels that are 25 ft high with a haunch depth of 6 in. beyond the face of the panel. Long-term roof movement is expected to be $^1/_4$ in.

Tolerance items to consider (refer to Fig. 13.4.1):

- Double-tee length tolerance ±1 in.
- Maximum plan variance ± $^1/_2$ in.
- Variation from plumb $^1/_2$ in. per 10 ft

Problem:

Find the minimum acceptable clearance.

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Solution:

Step 1: Determine maximum component sizes.

(Refer to Table 13.2.1)

Maximum double-tee length	= +1 in.
Wall thickness	= +$^1/_4$ in.
Initial clearance chosen	= $^3/_4$ in. per end

Step 2: Component movement.

Long-term shrinkage and creep will increase the clearance, so this movement can be neglected in the initial clearance determination, although it must be considered structurally.

Required clearance adjustment as a result of component movement	0
Clearance chosen (from step 1)	$^3/_4$ in.

Step 3: Other erection tolerances.

If the ribbed wall panel is set inward toward the building interior $^1/_2$ in. and erected plumb, this would suggest the clearance should be increased by $^1/_2$ in. However, if the panel is erected out of plumb outward $^1/_2$ in., no clearance adjustment is needed.

Clearance adjustment required for erection tolerances	= 0
Clearance chosen (from step 1)	= $^3/_4$ in.

Step 4: Erection considerations.

If all components are fabricated perfectly, then the joint clearance is $^3/_4$ in. at either end ($1^3/_4$ in. total). This is ample space for erection. If all components are at maximum size variance, maximum inward plan variance, and maximum inward variance from plumb, then the total clearance is zero. This is undesirable, as it would require some rework during erection. A judgment should be made as to the likelihood of maximum product and erection tolerances all occurring in one location. If the likelihood is low, the $^3/_4$ in. clearance does not need adjustment, but, if the likelihood is high, the engineer might increase the clearance. In this instance, the likelihood has been judged low; therefore, no adjustment has been made.

Clearance chosen (from step 1)	= $^3/_4$ in.

EXAMPLE 13.4.1
Clearance Determination – Single-Story Industrial Building (cont.)

Step 5: Economy.

In single-story construction, increasing the clearance beyond $^3/_4$ in. is not likely to speed up erection as long as product tolerances remain within allowables. Adjustment is not required for economic considerations.

Step 6: Review structural considerations.

Allowing a setback from the edge of the corbel, assumed in this instance to have been set by the engineer at $^1/_2$ in. plus the clearance, the bearing is 4 in. There should be space to allow component movement. The engineer judges this to be acceptable from a structural and architectural point of view and no adjustment is required for structural considerations.

Step 7: Check for minimum component sizes.

(Refer to Table 13.2.1)

Tee length	–1 in. ($^1/_2$ in. each end)
Wall thickness	–$^1/_8$ in.
Bearing haunch	No change
Clearance chosen	$^3/_4$ in.
Minimum bearing with setback	+4 in.

(OK in this instance)
Wall plumbness would also be considered in an actual application.

Step 8: Solution.

Minimum clearance used $^3/_4$ in. per end

(Satisfies all conditions considered.)

Note: For simplicity in this example, end rotation, flange skew, and global skew tolerances have not been considered. In an actual situation, these issues should also be considered.

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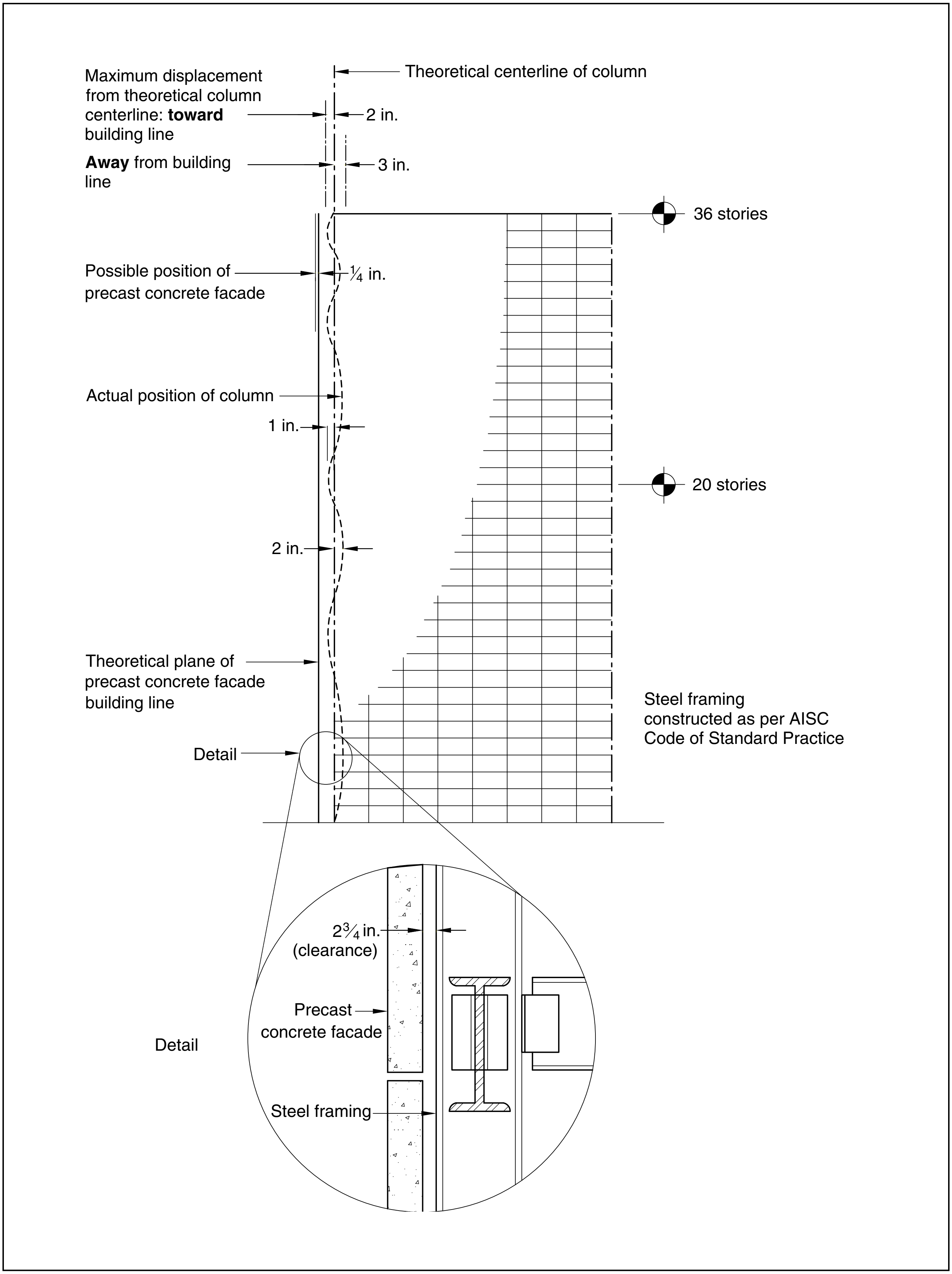

Fig. 13.4.2 Clearance example – high-rise steel-frame structure.

EXAMPLE 13.4.2
Clearance Determination – High-Rise Steel-Frame Structure

Given:

A 36-story, steel-frame structure, with precast concrete cladding, steel tolerances per AISC 303-05 and negligible component movement. In this example, precast concrete tolerance for variation in plan is ± $^1/_4$ in. Refer to Fig. 13.4.2.

Problem:

Determine whether the panels can be erected plumb and determine the minimum acceptable clearance at the 36th story.

Solution:

Step 1: Product tolerances.

(refer to Table 13.2.1)

Precast concrete cladding thickness	= + $^1/_4$ in., – $^1/_8$ in.
Steel width	= + $^1/_4$ in., – $^3/_{16}$ in.
Steel sweep (varies)	= ± $^1/_4$ in. (assumption)
Initial clearance chosen	= $^3/_4$ in.

Step 2: Component movement.

For simplification, assume this can be neglected in this example.

Step 3: Other erection tolerances.

Steel variance in plan, maximum	= 2 in.
Initial clearance	= $^3/_4$ in.
Clearance chosen	= 2$^3/_4$ in.

Step 4: Erection considerations.

No adjustment required for erection considerations.

Step 5: Economy.

Clearance chosen = 2$^3/_4$ in.
Increasing clearance will not increase economy.
No adjustment for economic considerations.

Step 6: Structural considerations.

Clearance chosen = 2$^3/_4$ in.
Expensive connection, but possible. No adjustment.

Step 7: Check minimum component sizes at 36th story (refer to Table 13.2.1).

Initial clearance	= 2$^3/_4$ in.
Precast concrete thickness	= $^1/_8$ in.
Steel width	= $^3/_{16}$ in.
Steel sweep	= $^1/_4$ in.
Steel variance in plan minimum	= 3 in.
Clearance calculated	= 6$^5/_{16}$ in.

EXAMPLE 13.4.2
Clearance Determination – High-Rise Steel-Frame Structure (cont.)

Step 8: Solution.

A clearance of over 6 in. would require an extremely expensive connection for the precast concrete panel, and would produce high torsional stresses in the steel supporting beams. The 6 in. clearance is not practical, although the $2^3/_4$ in. minimum initial clearance is still needed. Either the precast concrete panels should be allowed to follow the steel frame or the tolerances for the exterior columns need to be made more stringent, such as the AISC requirements for elevator columns. The most economical choice will likely be for the precast concrete panels to follow the steel frame.

Minimum clearance used: = $2^3/_4$ in. Use 3 in.
Allow panels to follow the steel frame.

13.5 Interfacing Tolerances

13.5.1 General

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In interfacing with other materials, the tolerances may be very system-dependent. For example, different brands of windows may have different tolerance requirements. If product substitutions are made after the initial design is complete, the interface details must be reviewed for the new system. Following is a partial checklist for consideration in determining interfacing requirements:

- structural requirements
- volume change
- exposure and corrosion protection
- waterproofing
- drainage requirements
- architectural requirements
- dimensional considerations
- vibration considerations
- fire-rating requirements
- acoustical considerations
- economics
- manufacturing/erection considerations

13.5.2 Interface Design Approach

The following approach is one method of organizing the task of designing the interface between two systems.

Step 1: Review the interface between the two systems, show shape and location, and determine contractual responsibilities. For example, the precast concrete panel is furnished by the precast concrete manufacturer, the window is furnished and installed by the window manufacturer, and the sealant between the window and the precast concrete is furnished and installed by the general contractor.

Step 2: Review the functional requirements of each interfacing system. For example, the building drain line must have a flow line slope that allows for adequate drainage. This will place limits on where the line must penetrate precast concrete units. Note whether this creates problems such as conflict with prestressing strands.

Step 3: Review the tolerances of each interfacing system. For example, determine the external tolerances on the door jamb from the manufacturer's specifications. Determine the tolerance on a large-panel door blockout from the precast concrete product tolerances. For the door installation, determine the floor surface tolerance in the area of the door swing path.

Step 4: Review the operational clearances required. For example, determine the magnitude of operational clearances that are needed to align the door so it functions properly, and then choose dimensions that include necessary clearances.

Step 5: Review the compatibility of the interface tolerances. Starting with the least precise system, check the tolerance requirements and compare them with the minimum and maximum dimensions of the interfacing system. If interferences result, alter the nominal dimension of the appropriate system. For example, it is usually more economical to make a somewhat larger or smaller opening than to specify a non-standard window size.

Step 6: Review assembly and installation procedures for the interfacing systems to ensure compatibility. Show the preferred adjustments to accommodate the tolerances of the systems. Consider such things as minimum bearing areas, minimum and maximum joint gaps, and other dimensions that will vary as a result of interface tolerances. Consider economic trade-offs such as in-plant work versus field work, and minor fit-up rework versus more restrictive tolerances.

Step 7: Review the final project specifications as they relate to interfacing. Be aware of the interface consequences of subsystem substitutions that might be made during the final bidding and procurement.

13.5.3 Characteristics of the Interface

The following list of questions will help to define the nature of the interface:

1. What specifically is to be interfaced?
2. How does the interface function?
3. Is there provision for adjustment upon installation?
4. How much adjustment can occur without rework?
5. What are the consequences of an interface tolerance mismatch?
   - Rework requirements (labor and material)
   - Rejection limits
6. What are the high material-cost considerations of the interface?
7. What are the high labor-cost considerations of the interface?
8. What are the normal tolerances associated with the systems to be interfaced?
9. Are the system interface tolerances simple planar tolerances or are they more complex and three-dimensional?
10. Do all of the different products of this type have the same interface tolerance requirements?
11. Does the designer of the precast concrete system have control over all of the aspects of the interfaces involved? If not, what actions need to be taken to accommodate this?

Listed below are common characteristics to be considered for most systems of the type listed:

1. Windows and doors
   - No gravity load transfer through window element
   - Compatible with air and moisture sealant system
   - Open/close characteristics (swing or slide)
   - Compatibility with door locking mechanisms

2. Mechanical equipment
   - Duct clearances for complex prefabricated ductwork
   - Large-diameter prefabricated-pipe clearance requirements
   - Deflections from forces associated with large-diameter piping and valves
   - Expansion/contraction allowances for hot and cold piping
   - Vibration isolation/transfer considerations
   - Acoustical shielding considerations
   - Hazardous gas/fluid containment requirements

3. Electrical equipment
   - Multiple mating conduit runs
   - Prefabricated cable trays
   - Embedded conduits and outlet boxes
   - Corrosion related to DC (direct current) power
   - Special insert placement requirements for isolation
   - Location requirements for embedded grounding cables
   - Shielding clearance requirements for special clean electrical lines

4. Elevators and escalators
   - Elevator guide location requirements
   - Electrical conduit location requirements
   - Elevator door mechanism clearances
   - Special insert placement requirements
   - Door opening size

5. Architectural cladding
   - Joint tolerance for sealant system
   - Flashing and reglet fit-up (Lining up cast-in reglets from panel to panel is very difficult and often costly. Surface-mounted flashing should be considered.)
   - Expansion and contraction provisions for dissimilar materials
   - Effects of rotation, deflection, and differential thermal gradients

6. Structural steel and miscellaneous steel
   - Details to prevent rust staining of concrete
   - Details to minimize potential for corrosion at field connections between steel and precast concrete
   - Coordination of structural steel expansion/contraction provisions with those of the precast concrete system
   - Special provisions for weld plates or other attachment features for steel structures
   - Consideration of thermal insulation and fireproofing requirements

7. Masonry
   - Coordination of masonry expansion/contraction provisions with those of the precast concrete system
   - Detailing to ensure desired contact bearing between masonry and precast concrete units
   - Detailing to ensure desired transfer of load between masonry shear wall and precast concrete frame
   - Requirements for dovetail anchors—field installation always preferred

8. Roofing
   - Roof camber, both upon erection and over the long-term, as it relates to roof drain placement
   - Fit-up of prefabricated flashing
   - Dimensional effects of added material during reroofing
   - Coordination of structural control joint locations with roofing system expansion/contraction provisions
   - Location of embedded heating, ventilating, and air-conditioning unit supports
   - Deflections due to live load and added equipment dead loads

9. Waterproofing
    - Location and dimensions of flashing reglets grooves
    - Coordination of waterproofing system requirements with structural system expansion/provisions
    - Special details around special penetrations

10. Interior finishes
    - Floors, walls, and ceilings
    - Joints between precast concrete members for direct-carpet overlay
    - Visual appearance of joints for exposed ceilings
    - Fit-up details to ensure good appearance of interior corners
    - Appearance of cast-in-place to precast concrete interfaces

11. Interior walls and partitions
    - Clearance for prefabricated cabinetry
    - Interfacing of mating embedded conduit runs