

____ STRUCTURAL DEVIATIONS AND SURFACE TOLERANCES FOR CONCRETE CONSTRUCTION

a. General. - Structural deviations are defined as allowable variations from specified lines, grades, and dimensions. Allowable variations from specified lines, grades, and dimensions are listed in table ____ (Deviations from specified lines, grades, and dimensions) in subparagraph b. below. Surface tolerances are the maximum allowable magnitude of the surface irregularities. Allowable magnitudes for concrete surface irregularities are specified in table ____ (Concrete surface tolerances) in subparagraph d. below ¹(and on drawings _____). Surface tolerances for specific structures are listed in tables ____ (Formed surfaces) and ____ (Unformed surfaces) in paragraph ____ (Finish, Surface Tolerances, and Curing Schedule).

The intent of this paragraph is to establish structural deviations and surface tolerances that are consistent with modern construction practice, yet are governed by the effect that permissible variations may have upon a structure. The Government reserves the right to diminish the structural deviations and/or surface tolerances set forth herein if such variations impair the structural action, operational function, or architectural appearance of a structure or portion thereof.

Concrete shall be within all stated variations even though more than one may be specified for a particular concrete structure: Provided, That the specified variation for one element of a structure shall not apply when it will permit another element of the structure to exceed its allowable variation. Where variations are not specified or shown on the drawings for a particular structure, variations shall be those specified for similar work. As an exception to the clause in subsection I.3 entitled "Order of Precedence - Construction Reclamation," specific tolerances shown on the drawings in connection with any dimension shall govern. The Contractor shall be responsible for finishing the concrete and for setting and maintaining concrete forms within the limits necessary to ensure that the completed work will be within the variations specified. Concrete work that does not conform to the limits specified shall be remedied in accordance with subparagraphs d. and e. below.

b. Structural deviations. - Variations from specified lines, grades, and dimensions in hardened concrete structures shall be checked by the Contractor and will be subject to such inspection and measurement as needed to determine that the structures are within the tolerances specified in table ____ (Deviations from specified lines, grades, and dimensions).

Variation is defined as the distance between the actual position of the structure or any element of the structure and the specified position in plan for the structure or the particular element. Plus or minus variations, shown as plus (+) or minus (-), indicate a permitted actual position up or down and in or out from the specified position in plan. Variations not designated as (+) or (-) indicate the maximum deviation permitted between designated successive points on the completed element of construction. Specified position in plan is defined as the lines, grades, and dimensions described in these specifications or shown on the drawings or as otherwise prescribed by the Contracting Officer.

Table _____. - Deviations from specified lines, grades, and dimensions

A. ¹[Structural deviations for switchyard structures. -

1. Footings:

(a) Variation in length and width dimensions
from those specified -12 mm
. +50 mm

(b) Horizontal misplacement or eccentricity:

(1) 2 percent of the footing width in the
direction of misplacement, but not more
than 50 mm

(c) Reduction in thickness from that specified 5 percent
of specified
thickness,
not to
exceed 25 mm

2. Variation from plumb or specified batter for lines and surfaces of piers, stems, and walls:

(a) When overall height of line or surface is:

Less than 3 meters ± 6 mm
3 meters or more ± 10 mm

(b) For any two successive intermediate points
on the line or surface separated by:

3 to 6 meters, inclusive 6 mm
More than 6 meters 10 mm

3. Variation from level or specified grades for slabs:

(a) When overall length of line or surface is:

Less than 3 meters ± 6 mm
3 to 6 meters, inclusive ± 10 mm
More than 6 meters -20 mm

(b) For any two successive intermediate points on the line or surface separated by:

3 to 6 meters, inclusive 6 mm
More than 6 meters 10 mm

4. Variation in cross-sectional dimensions of piers and stems from those specified and in thicknesses of slabs and walls from those specified -6 mm
. +12 mm

5. Variation from specified elevation for top of concrete for foundations ±12 mm

6. Variation from specified grade or alignment for cable trenches:

(a) When overall length is:

Less than 3 meters ±6 mm
3 to 6 meters, inclusive ±10 mm
More than 6 meters ±20 mm

(b) For any two intermediate points separated by:

3 to 6 meters, inclusive 6 mm
More than 6 meters 10 mm

B. ¹[Structural deviations for powerplant and pumping plant structures and other buildings. -

1. Footings:

(a) Variation in length and width dimensions from those specified -12 mm
. +50 mm

(b) Horizontal misplacement or eccentricity:

(1) 2 percent of footing width in direction of misplacement, but not more than 50 mm

(c) Reduction in thickness 5 percent
of specified
thickness

2. Variation of horizontal dimensions at all floor and roof levels from specified position in plan:

(a) Overall building dimensions ± 12 mm per
30 meters
length with
maximum for
entire length
of ± 25 mm

(b) Overall bay dimensions as limited by
2(c) below but not to exceed ± 10 mm

(c) Intermediate dimensions for column, wall,
and partition locations:

(1) For dimensions less than 3 meters ± 6 mm

(2) For dimensions equal to or greater than
3 meters but less than 6 meters ± 10 mm

(3) For dimensions 6 meters or more ± 12 mm

3. Variation of vertical dimensions from specified position in plan:

(a) Overall building dimensions ± 12 mm

(b) Overall story height as limited by 3.(c)
below but not to exceed ± 10 mm

(c) Intermediate dimensions:

(1) For dimensions less than 3 meters ± 6 mm

(2) For dimensions which are
3 to 6 meters, inclusive ± 10 mm

(3) For dimensions 6 meters or more ± 12 mm

4. Variation from plumb or specified batter for lines and surfaces of columns, piers, and walls and for arrises:

(a) When overall height of line or surface is:

Less than 3 meters ± 6 mm
3 to 6 meters, inclusive ± 10 mm
More than 6 meters, but less than 12 meters ± 12 mm
12 meters or more ± 25 mm

(b) For any two successive intermediate points on the line or surface separated by:

3 to 6 meters, inclusive 6 mm
More than 6 meters 10 mm

5. Variation from plumb for lines and surfaces of corner columns, control joint grooves, and other conspicuous lines:

(a) When overall height of line or surface is:

Less than 3 meters ± 6 mm
3 to 6 meters, inclusive ± 10 mm
More than 6 meters ± 12 mm

(b) For any two successive intermediate points on the line or surface separated by:

3 to 6 meters, inclusive 6 mm
More than 6 meters 10 mm

6. Variation from level or established grades for floors, roof decks, ceilings, beam soffits, and arrises:

(a) When overall length of line or surface is:

Less than 3 meters ± 6 mm
3 to 6 meters, inclusive ± 10 mm
More than 6 meters, but less than 12 meters ± 12 mm
12 meters or more ± 20 mm

(b) For any two successive intermediate points on the line or surface separated by:

3 to 6 meters, inclusive 6 mm
More than 6 meters 10 mm

7. Variation from level or specified grades for exposed

lintels, sills, parapets, horizontal grooves, and other conspicuous lines:

(a) When overall length of line or surface is:

Less than 3 meters ± 6 mm
3 to 6 meters, inclusive. ± 10 mm
More than 6 meters ± 12 mm

(b) For any two successive intermediate points on the line or surface separated by:

3 to 6 meters, inclusive 6 mm
More than 6 meters 10 mm

8. Variation in location from specified position in plan of sleeves and wall openings ± 12 mm

9. Variation in sizes from those specified for sleeves, floor openings, and wall openings, except wall openings for swinging doors ¹(and louvers without tubular frames) ± 6 mm

10. Variation in sizes from those specified for wall openings for swinging doors ¹(and louvers without tubular frames) -0 mm
..... +6 mm

11. Variation in cross-sectional dimensions from those specified for columns and beams and in thicknesses from those specified for slabs and walls -6 mm
..... +12 mm

12. Variation in rise and tread of steps from that specified:

(a) Flight of stairs:

Rise ± 3 mm
Tread ± 6 mm

(b) Consecutive steps:

Rise 2 mm

Tread 3 mm

C. ¹[Structural deviations for canal lining. -

1. *Departure from established alignment (centerline)..... ±50 mm
on tangents,
±100 mm

on curves

2. *Departure from established profile grade ±25 mm

Provided, That minimum cover requirement for reinforcement is maintained

* Any departure from alignment or grade shall be uniform. No other departure and no correction in alignment or grade shall be made in less than 6 meters.

3. Reduction in thickness of unreinforced lining 10 percent
of specified
thickness:
Provided, That
average thickness
is not less than
specified thickness

4. Reduction in thickness of reinforced lining 0 percent
of specified
thickness

5. Variation from specified width of section at any height ±(0.25 percent
of specified
width plus
25 mm)

6. Variation from established height of lining ±(0.50 percent
of established
height plus
25 mm)

D. ¹[Structural deviations for canal and pipeline structures. -

1. Footings:

(a) Variation of length and width dimensions
from those specified -12 mm
..... +50 mm

(b) Misplacement or eccentricity:

(1) 2 percent of the footing width in the
direction of misplacement but not
more than 50 mm

(c) Reduction in thickness from that
specified 5 percent
specified

thickness,
not to exceed
25 mm

of

2. Monolithic siphons and culverts:

(a) Departure from established alignment ± 50 mm

(b) Departure from established profile
grade ± 50 mm

(c) Variation from specified thickness:

At any point -2.5 percent
of specified
thickness
or -6 mm,
whichever
is greater

At any point +5 percent
of specified
thickness

+12 mm,

is greater

whichever

or

(d) Variation from specified inside
dimensions ± 0.5 percent
of inside
dimensions

3. Checks, overchutes, drops, turnouts, inlets, chutes, and similar structures:

(a) Departure from established alignment ± 25 mm

(b) Departure from established grade ± 25 mm

(c) Variation from plumb or specified batter for lines and surfaces of columns, piers, walls, and for arrises:

(1) When overall length of line or surface is:

Less than 3 meters Exposed ± 10 mm
..... Buried ± 20 mm
3 meters or more Exposed ± 12 mm
..... Buried ± 25 mm

(2) For any two successive intermediate points on the line or surface separated by:

3 to 6 meters, inclusive Exposed 10 mm
..... Buried 20 mm
More than 6 meters Exposed 12 mm
..... Buried 25 mm

4. Variations from level or specified grades for slabs, beams, and horizontal grooves:

(a) When overall length of line or surface is:

Less than 3 meters Exposed ± 10 mm
..... Buried ± 20 mm
3 meters or more Exposed ± 12 mm
..... Buried ± 25 mm

(b) For any two successive intermediate points on the line or surface separated by:

3 to 6 meters, inclusive Exposed 10 mm
..... Buried 20 mm
More than 6 meters Exposed 12 mm
..... Buried 25 mm

2. Variation of controlling dimensions for each structure from specified position in plan with reference to dam axis:

- (a) Overall dimensions Exposed +50 mm
..... Buried ± 65 mm

3. Variation from centerline specified in plan for ³(spillway, outlet works, _____):

- (a) For overall length, except for buried construction ± 25 mm
- (b) For buried construction ± 50 mm
- (c) For any span less than 6 meters except for buried construction ± 12 mm

4. Variation from specified grade for ³(spillway, outlet works, _____):

- (a) For ogee crest of uncontrolled hydraulic structures ± 12 mm
- (b) For all other surfaces ± 25 mm
- (c) For any span less than 3 meters 12 mm

5. Variation from plumb, specified batter, or specified curved profile for lines and surfaces of columns, walls, piers, buttresses, arch sections, vertical joint grooves, and arrises:

(a) Exposed construction, except elevator shafts:

(1) When overall height of line or surface is:

- Less than 3 meters ± 12 mm
- 3 meters or more ± 20 mm

(2) For any two successive intermediate points on the line or surface separated by:

- 3 to 6 meters, inclusive 12 mm
- More than 6 meters 20 mm

(b) Elevator shafts:

(1) When overall height of line or surface is:

Less than 3 meters	±12 mm
3 meters or more	±25 mm

(2) For any two consecutive points on the line or surface separated by:

3 to 6 meters, inclusive	12 mm
More than 6 meters	20 mm

(c) Buried construction:

(1) When overall height of line or surface is:

Less than 3 meters	±25 mm
3 meters or more	±40 mm

(2) For any two successive intermediate points on the line or surface separated by:

3 to 6 meters, inclusive.	25 mm
More than 6 meters	40 mm

6. Variation from level or specified grades for slabs, beams, soffits, horizontal joint grooves, and arrises:

(a) Exposed construction:

(1) When overall length of line or surface is:

Less than 3 meters	±6 mm
3 meters or more	±12 mm

(2) For any two successive points on the line or surface separated by:

3 to 6 meters, inclusive	6 mm
More than 6 meters	12 mm

(b) Buried construction:

(1) When the overall length of line or surface is:

Less than 3 meters ± 12 mm
3 meters or more ± 25 mm

(2) For any two successive points on the line
or surface separated by:

3 to 6 meters, inclusive 12 mm
More than 6 meters 25 mm

7. Variation in cross-sectional dimensions from
those specified for columns, beams,
buttresses, piers, and similar members -6 mm
. +12 mm

8. Variation in the thickness of slabs, walls,
arch sections, and similar members from that
specified -6 mm
. +12 mm

9. Variation from plumb or level for invert and
sidewalls of each wheel-mounted gate slot, for
sidewalls of each penstock stoplog guide, and
for similar watertight joints:

(a) When overall length of line is:

Less than 3 meters ± 3 mm
3 meters or more ± 20 mm

(b) For any two successive intermediate
points on the line or surface separated by:

3 to 6 meters, inclusive. 3 mm
More than 6 meters 20 mm

10. Variation from that specified in distance
between vertical sidewalls of each wheel-
mounted gate slot and between sidewalls of
penstock stoplog guides ± 12 mm

11. Variation in location from specified
position in plan of sleeves, floor openings,
and wall openings ± 12 mm

12. Variation in sizes from those specified
for sleeves, floor openings, and wall
openings ± 6 mm

F. ¹[Structural deviations for bridges. -

1. Departure from established alignment ± 25 mm

2. Footings:

(a) Variation in length and width
dimensions from those specified -12 mm
..... $+50$ mm

(b) Horizontal misplacement or
eccentricity:

(1) 2 percent of the footing width in
the direction of misplacement, but
not more than 50 mm

(c) Reduction in thickness 5 percent
of specified
thickness,
not to exceed
25 mm

3. Variation from plumb or specified batter
for lines and surfaces of piers and walls
and for arrises:

(a) Exposed construction:

(1) When overall height of line or surface is:

Less than 3 meters ± 10 mm
3 meters or more. ± 12 mm

(2) For any two successive intermediate
points on the line or surface separated by:

3 to 6 meters, inclusive 10 mm
More than 6 meters 12 mm

(b) Buried construction:

(1) When overall height of line or surface is:

Less than 3 meters ± 20 mm
3 meters or more ± 25 mm

(2) For any two successive intermediate points
on the line or surface separated by:

3 to 6 meters, inclusive 20 mm
More than 6 meters 25 mm

4. Variation from level or specified grades
for slabs, other than bridge deck; beams;
horizontal grooves; railing offsets; and
diaphragms:

(a) Exposed construction:

(1) When overall length of line or surface is:

Less than 3 meters ± 10 mm
3 meters or more ± 12 mm

(2) For any two successive intermediate
points on the line or surface separated by:

3 to 6 meters, inclusive 10 mm
More than 6 meters 12 mm

(b) Buried construction:

(1) When overall length of line or surface is:

Less than 3 meters ± 20 mm
3 meters or more ± 25 mm

(2) For any two successive intermediate
points on the line or surface separated by:

3 to 6 meters, inclusive 20 mm
More than 6 meters 25 mm

5. Departure of bridge deck and rails from
specified grades ± 6 mm

6. Variation in cross-sectional dimensions from those specified for piers; slabs, other than bridge deck; walls; beams; and similar parts of bridge structures -6 mm

..... +12 mm

7. Variation from that specified in the thickness of bridge slabs -3 mm

..... +12 mm

G. Structural deviations for tunnel lining and monolithic conduits. -

1. Tunnels and conduits with flow velocity less than or equal to 6 meters per second:

(a) Departure from established alignment (centerline) ± 50 mm

(b) Departure from specified grade ± 25 mm

2. Tunnels and conduits with flow velocity greater than 6 meters per second:

(a) Departure from established alignment (centerline) ± 25 mm

(b) Departure from specified grade ± 12 mm

3. Variation in the thickness at any point from that specified:

(a) Tunnel lining -0

(b) Conduits -2.5 percent
or 6 mm,
whichever
is greater

(c) Conduits +5 percent
or 12 mm
whichever
is greater

4. Variation from specified inside dimensions 0.5 percent

c. Concrete surface irregularities. -

(1) General. - Bulges, depressions, and offsets are defined as concrete surface irregularities (or roughness). Concrete surface irregularities are classified as "abrupt" or "gradual" and allowable tolerances are listed in table _____ (Concrete surface tolerances). A concrete surface tolerance is designated by a capital "T" followed by a number 1 through 4(5). Concrete surface tolerance designations are separate from concrete surface finishes and concrete structural deviations.

(2) Abrupt surface irregularities. - Abrupt surface irregularities are defined herein as offsets such as those caused by misplaced or loose forms. Abrupt surface irregularities are further defined as isolated irregularities in which the maximum dimension of the irregularity perpendicular to the surface is greater than the maximum dimension of the irregularity in the plane of the surface. Also, abrupt surface irregularities include all incidences of isolated surface irregularities which exceed the gradual irregularity specifications set forth herein. Abrupt surface irregularities are measured as specified in subparagraph f. below.

(3) Gradual surface irregularities. - Gradual surface irregularities are defined herein as bulges and depressions resulting in gradual changes on the concrete surface. Gradual surface irregularities are further defined as isolated undulations on the concrete surface. The maximum dimension of the undulation perpendicular to the surface is small relative to the maximum dimension of the undulation in the plane of the surface. Gradual surface irregularities are measured as specified in subparagraph f. below.

(4) The magnitude of surface irregularities of formwork and finished concrete surfaces shall be checked by the Contractor to ensure that the concrete surfaces are within specified tolerances. The Government will also make such checks of hardened concrete surfaces as determined necessary to ensure compliance with these specifications.

d. Concrete surface tolerances. -

Table _____. - Concrete surface tolerances.

Concrete surface tolerance	Maximum allowable concrete surface irregularity	
	Abrupt	Gradual
T1	25 mm	1/4 mm/mm
T2	12 mm	1/8 mm/mm

T3	6 mm	1/16 mm/mm
T4	3 mm	1/32 mm/mm
T5	1 mm	1/120 mm/mm

e. Repair of hardened concrete not within specified tolerances. -

Hardened concrete which is not within specified tolerances shall be repaired to bring it within those tolerances. Such repair shall be in accordance with paragraph _____ (Repair of Concrete), and shall be accomplished in a manner approved by the Contracting Officer. Concrete repair to bring concrete within tolerances shall be done only after consultation with a Government inspector regarding the method of repair. The Contractor shall notify the Government as to the time when repair will be performed.

Concrete which will be exposed to public view shall be repaired in a manner which will result in a concrete surface with a uniform appearance. Grinding of concrete surfaces exposed to view shall be limited in depth such that no aggregate particles are exposed more than 2 mm in cross section at the finished surface. Where grinding has caused or will cause exposure of aggregate particles greater than 2 mm in cross section at the finished surface, concrete shall be repaired by excavating and replacing the concrete.

f. Field verification of concrete surface tolerances. - To determine compliance of a concrete surface with the surface tolerance specifications, the following evaluation and measuring techniques shall be employed:

(1) Evaluating surface roughness. - The following steps describe the evaluation process for concrete surface roughness:

(a) Measure the roughness height or depth and check for compliance with the values given in tables _____ (Concrete surface tolerances) and _____ (Deviations from specified lines, grades, and dimensions). -

(aa) If the measured height or depth of the roughness is less than the value given by the abrupt tolerance specification, and if the height or depth of the roughness does not cause the structure to exceed any applicable value specified in table _____ (Deviations from specified lines, grades, and dimensions), then the surface roughness is acceptable and no further evaluation is required.

(bb) If the roughness height or depth exceeds the abrupt tolerance specification, the roughness slope must be determined for comparison to the gradual tolerance specification.

(b) Measure the roughness length and determine the roughness slope by dividing the roughness height or depth by the roughness length (see figure 1 for details). -

(aa) If the roughness slope is greater than the slope specified by the gradual tolerance specification, then the roughness does not meet the specifications and shall be repaired by and at the expense of the Contractor.

(bb) If the roughness slope is less than the gradual slope specified and if the gradual roughness does not cause the structure to exceed allowable structural deviations, as specified in table _____ (Deviations from lines, grades, and dimensions), the roughness is acceptable.

Figure 1

(2) Measuring surface roughness. - Two examples, illustrating how to make the necessary surface measurements for typical roughness, are given below:

(a) Case 1. - Roughness protruding above the surface. - A roughness protruding above the surface should be measured with a straightedge that is at least 20 times longer than the roughness height being measured. Position the straightedge with one end resting on top of the roughness, as shown in figure 2 (Case 1). Determine the roughness height by measuring the maximum gap that occurs normal to the straight edge. Also, note the position on the straightedge from which the normal distance is measured. To determine the roughness length, measure the distance along the straightedge from the point where the height was measured to the point of contact between the straightedge and the top of the roughness. The roughness slope is defined as the ratio of the roughness height to the roughness length. As roughness is seldom symmetric, moving the position of the straightedge about the roughness may be necessary to locate the point where the maximum height and slope exists.

(b) Case 2. - Roughness extending below the surface. - A roughness occurring as an indentation to the surface is measured by placing the straightedge across the indentation, as shown in figure 2 (Case 2). Measure the maximum gap between the straightedge and the surface and note the location of the measurement on the straightedge. From the point of the depth measurement, measure along the straightedge in both directions to the point of contact with the surface. The shortest length measured is used as the roughness length. Divide the roughness depth by the roughness length to determine the roughness slope.

A simple measuring device can be constructed to perform the surface tolerance measurements and evaluation process directly and quickly. Information concerning concrete tolerance measuring devices can be obtained from the Bureau of Reclamation, Attn: D-3730, PO Box 25007, Denver, CO 80225, telephone (303) 236-5989.

Figure 2

g. Prevention of repeated failure to meet tolerances. - When concrete placements result in hardened concrete that does not meet specified tolerances, the Contractor shall, upon request, submit to the Government an outline of all preventive actions, such as modifications to forms, modified procedure for setting screeds, and different finishing techniques, to be implemented by the Contractor to avoid repeated failures. The Government reserves the right to delay concrete placements until the Contractor implements preventive actions which have been approved by the Contracting Officer.

¹Delete or revise as required.

²There may be circumstances (especially in fish ladder work) where minus 6 mm or plus 12 mm may be critical. These special circumstances should be clearly stated in the body of the specifications paragraph. Contact designer (D-3122) for clarification.

³Insert applicable structure.

⁴Revise as required. Architectural surfaces may require surface tolerance T6 or T7 in accordance with paragraph "Finish, Surface Tolerances, and Curing Schedule."

8-1-88 Revisions: Minor revisions.