Appendix E Construction Tolerances

The following explanation of construction tolerances is provided to give the QA inspector an understanding of tolerances that are generally accepted in the construction industry. Any tolerances given in a contract, either directly or by reference, take precedence over generally accepted tolerances. The QA inspector shall consult with the project engineer whenever there is a question concerning allowable tolerances.

All construction work has tolerances to allow for inherent variances in construction materials and workmanship skills. Many of these variances are an integral part of quality designs, which can be related to minimum required safety factors. Zero tolerance in construction is not feasible or necessary in the NRCS. Tolerance is defined as the:

- permissible range of variation in a dimension of an object
- permissible variation of an object in some characteristic such as hardness, density, or size
- permissible deviation from plan alignment, location or grade

Tolerances in construction are generally a variation in a dimension, construction limit, or physical characteristic of a material. They are a practical variation related to the function of the material or finished work and commonly accepted standards of the construction industry.

Tolerances vary from a fraction of an inch to feet. There is, for example, a great deal of difference in the amount of acceptable tolerance in the invert of a cast-in-place conduit subject to cavitation velocities compared to overfill on an earthfill embankment. Experienced contractors know acceptable (industry standard) tolerances for various types of construction work and, unless advised otherwise, will expect to be permitted to operate within the limits of tolerances in which they are familiar.

The following excerpt from the Handbook of Heavy Construction emphasizes the importance of tolerances and where the responsibility generally lies:

> *The matter of job tolerances and good workmanship is a very important consideration in the inspection of construction work. The Resident Engineer must realize that weather, time, the construction methods and materials often control and even dictate the accuracy and quality of the completed job. Of course, some consideration should have been given to these items in the original preparation of the plans and specifications. Also good specifications will stipulate some working tolerances, which will assist the Resident Engineer. However, appreciation of job tolerances becomes primarily the problem of the Resident Engineer, who must decide and instruct his staff on the accuracy's to be expected of the Contractor on the various operations. This obviously requires experience and good judgment and should include such considerations as the function, stability and appearance of the work; the limits of workability of the materials being used, the mechanical limitations of first-class construction equipment to be used, etc. Probably the most common cause for controversies on the matter of job tolerances results from a Contractor using poor construction equipment or unskilled labor with which the desired final work cannot be produced. This generally requires a positive stand by the Resident Engineer and insistence that the Contractor either improves his present operations or gets something better on the job.*

Some tolerances are provided in the Construction Specifications and in ASTM Standards used for testing. The other source for tolerances that construction personnel must be familiar with is the established common usage or practice that represents the industry standard.

The following listed tolerances identify the more significant categories of work with cited references and description. Specific tolerances do not have to be displayed on the drawings or in the specifications, but should be established for each job prior to construction. The designer, project engineer, and QA inspector should have a common understanding of what tolerances will be allowed.

It must be recognized when making computations based on measurements involving tolerances that the results will only be as precise as the measurement. Therefore, the numerical precision used should be compatible and consistent with that of the measurement. In computing test results, for instance, carrying out numbers to places beyond that required by the test procedure is time consuming, provides opportunities for making computational errors, and may imply accuracy that does not exist. It is essential to know the job requirements for accuracy and use the rounding rules that produce the appropriate significant digits in the computations.

A. Excavation

1. Common excavation

a. Foundation—Cut at least to the grade designated on the plans with stable side slopes no steeper than specified. Additional depth by steepening the plan slopes may not be critical as long as this does not complicate dewatering or disposal of materials and the side slopes remain stable.

b. Channel excavation—The bottom grade should be at least to grade with possibly 0.5 foot below grade allowed. Drainage channels can typically be more generous on the over excavation due to initial siltation in the completed channel. Side slopes plus or minus 0.2 foot as long as humps or pockets are blended in.

c. Waterways and diversions—A closer tolerance is needed here to control velocity and erosion. Plus or minus 0.2 foot in the bottom grade may be allowed, as long as ponding does not occur. Side slopes plus or minus 0.2 foot as long as humps or pockets are blended in.

d. Principal spillway trench—Bottom grade should be close to that specified. A tolerance, usually plus or minus 0.10 foot, should be sufficient to lay the pipe to grade without excessive shimming, adjusting, or excavation to get the full cradle or bedding section under the pipe. The principal spillway pipe should be placed within plus or minus 0.05 foot of grade without any unspecified grade reversals.

e. Auxiliary spillways—The control or level section must be to plus or minus 0.10 foot (NRCS Technical Release 52). The inlet section is not critical, and plus or minus 0.30 foot will have little effect on function. The outlet channel should have the grade maintained lengthwise throughout the cross section to a tolerance of plus 0.10 foot and minus 0.20 foot. However, it is important that this section not vary significantly from plus or minus 0.10 foot from one side of the outlet channel to the other side.

2. Rock excavation

a. Foundation—Generally, conformity of rock surface is more important than final line and grade. A tolerance of plus 0.5 foot to minus 1.0 foot is reasonable in most rock. Dental concrete is often needed to gain conformity of surfaces.

b. Principal spillway trench and similar structure foundations—Closer tolerances due to a structure require plus 0.10 foot to minus 0.5 foot. This can be followed by dental concrete for minor adjustments and regular concrete for a pipe subcradle or working pad to maintain grade.

c. Auxiliary spillway—The tolerance for the level control section needs to be close, about plus 0.10 foot and minus 0.15 foot. If a concrete sill or a control crest is used, tolerance in the level section can be plus or minus 0.05 foot. The inlet channel can be plus 0.5 foot to minus 1.5 foot. The outlet needs to be plus 0.20 foot to minus 0.50 foot lengthwise and plus or minus 0.20 foot from one side to the other side of any given cross section.

Where overexcavation is required to remove unsuitable materials, it should be directed by the engineer and is typically handled as follows:

- At the level section, concrete should be used as required in other structural excavation situations.
- When the rock is to be covered with topsoil and vegetated, use compacted soils with medium plasticity to produce a dense flow-resistant material.

B. Earthfill

1. Finished fill slopes

Uniformity of grade from top to bottom and across slope is primarily for appearance and aesthetic considerations. Gradual changes of plus or minus 0.3 foot from plan line and grade are considered acceptable if overall appearance is acceptable.

2. Top of fills

Dams, dikes, levees, etc., should be completed to specified grade. Tolerance of plus 0.10 foot is acceptable.

C. Concrete

1. Formwork

References:
(1) American Concrete Institute (ACI), Publication SP–4, Formwork for Concrete

(2) ACI 347, Recommended Practice for Concrete Formwork ACI 117, Standard Tolerance for Concrete Construction and Materials

a. Cross-sectional dimensions of columns and beams and the thickness of slabs and walls:

Minus 1/4 inch to plus 1/2 inch

b. Irrigation canal linings:

Departure from profile grade plus or minus 1 inch. Departure from established alignment:

- On tangents, plus or minus 2 inches
- On curves, plus or minus 4 inches

Thickness of lining:

- Lining thickness 6 inches or less:
  – Plus 1 inch
  – Minus 0 inch
- Lining thickness more than 6 inches:
  10 percent of specified thickness provided the average thickness is maintained throughout

c. Monolithic culverts and siphons

Departure from established alignment plus or minus 1 inch

Departure from established profile grade plus or minus 1 inch

Variation in thickness:

– Minus the greater of 2 1/2 percent or 1/4 inch
– Plus the greater of 5 percent or 1/2 inch

2. Concrete surfaces

Reference:
U.S. Bureau of Reclamation Concrete Manual

F2 and U2 surfaces:

When different surface finishes are desired, use appropriate tolerances:

a. (F2) Formed surfaces, measured from 5-foot template

Depressions:

Gradual irregularity plus or minus 1/2 inch

b. (U2) Unformed surfaces, measure from 10-foot template. All surfaces plus or minus 1/4 inch.

3. Concrete cover or protection on rebars

Reference:
Concrete Reinforcing Steel Institute (CRSI), Recommended Practice for Placing Reinforcing Bars

Minus 1/4 inch to plus 1/2 inch while meeting steel placement tolerances

4. Steel placement

Reference:
Concrete Reinforcing Steel Institute (CRSI)

a. Cutting to length plus or minus 1 inch.

b. Hooked bars length out to out of hook plus or minus 1/2 inch for #7 or smaller bars plus or minus 1 inch for bars larger than #7.

c. Truss bars overall length plus or minus 1/2 inch for #7 or smaller bars plus or minus 1 inch for bars larger than #7.

d. Tension bars in beams or walls (distance from extreme compression fiber to the position shown on the drawings) plus or minus 3/8 inch for #8 or smaller bars and plus or minus 1/2 inch for bars larger than #8 bars.

e. Lap and splice location—Plus or minus 1 inch. Minimum 12-inch splice length.

f. Spacing—Minimum distance between bars plus or minus 1/4 inch. In uniform spacing (from theoretical location), plus or minus 2 inches.

g. Minimum cover—Tolerance from minimum cover specified or shown on the drawings minus 3/8 inch for #8 or smaller bars and minus 1/2 inch for bars larger than #8 bars.

5. Concrete materials

Reference:
Construction Specification 31 and/or 32

a. Cement—Batch weight within plus or minus 1 percent

b. Aggregate—Batch weights within plus or minus 2 percent

c. Additives (liquid)—Metered measure plus or minus l ounce

d. Water—Do not exceed maximum gallons established in the design mix

6. Concrete mixing

References:
(1) Construction Specification 31
(2) ACI 304

a. Mixing time—Under normal conditions, maximum time is 1 1/2 hours from the time water is introduced to the aggregates. The tolerance cannot be quantified, but this is an area where good technical judgment must be used. If placement is going well, materials looks good, temperature is still less than 85 degrees Fahrenheit, and most of the load is placed, time can be reasonably extended. If material is 85 degrees Fahrenheit or higher, placement not going well, load only partially placed, **do not** extend the permissible time of 1 1/2 hours.

b. Mixing revolutions are related to time, and the same technical judgment should be applied. Revolutions become especially critical in hot weather. Establish procedures early in the job to see that mixing revolutions are maintained as specified.

Note: The tolerances cited are an incomplete listing of those contained in the references. References used are considered to be industry standards and may be used in establishing tolerances for specific work.

D. Material testing

References:
Contract drawings and specifications with appropriate ASTM specifications or standards

1. Concrete testing

References
(1) Contract drawings, Construction Specification 31 and/or 32
(2) Appropriate ASTM standards
(3) ACI standards

a. Slump testing—Within the specified slump range, the slump must be within plus or minus 1/4 inch (ASTM C143). Some judgment may be used here especially on the low side of the range. The dry side is controlled to get a workable mix that can be placed in a tight or crowded form area. If placement is not difficult, low slump may be acceptable providing all other factors are met. Making a judgment on the high side involves the consideration of the portion of the load tested, total water content in the mix, temperature, consistency, and the appearance of the concrete. Since high slump often results in low test strength, all slumps at the high side of the slump range must be judged with caution.

b. Air content

References:
(1) ASTM C231
(2) ASTM C173

Air range is specified and measured to the nearest 1 percent. Judgment may be used on the low side depending on the actual location of the concrete with respect to exposure. At least 4 percent air content is required for good durability. The high side should never be violated and approached with extreme caution. High air content will reduce strength significantly. If air is running consistently below the range specified, a new design mix should be required.

c. Compressive strength specimens—Test cylinders or cores must be made and handled in accordance with ASTM C31 or C42. Tolerances and ranges in these specifications must be adhered to and adequately documented.

2. Soil testing

References
(1) Construction Specification 23
(2) Appropriate ASTM standards

a. For standard density and moisture content reference tests, ASTM D698 (Proctor Curve), the test should be reported to:

Moisture plus or minus 0.1 percent

Density plus or minus 0.1 pound per cubic foot

b. For field density and moisture testing the tests should be reported to: Moisture plus or minus 0.1 percent

Density plus or minus 0.5 pound per cubic foot

Field density can be obtained from ASTM D1556, D2922, D2937, or D2167. These methods are respectively: sand cone, nuclear gauge, drive cylinder, and rubber balloon.

Field moisture can be obtained from ASTM D2216, D3017, D4959, D4944, or D4643. These methods are respectively: drying oven, nuclear gauge, direct heating (frying pan), calcium carbide (Speedy Moisture Meter), or a microwave oven.

For the determination of percent compaction round off to the nearest 1 percent.

For the determination of specified moisture content round off to the nearest 0.5 percent

3. Filter and drain materials

References:
Construction Specification 24
ASTM C136

Percent passing sieve size:

Fines (No. 200 sieve), plus 0.5 percent

Other sizes, plus or minus 2 percent

E. Summary

The tolerances described in this appendix are the more common ones to be considered in construction activities. In each case, the tolerances are intended to maintain the integrity, quality, and function of the material or work involved. Tolerances used should be fully discussed at the preconstruction conferences and documented in the construction records.

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