Structural Services, Inc.

ENGINEERING BULLETIN

Floor Flatness and Levelness Testing – The Complete Specification

By **Wayne W. Walker, P.E., F.ACI; Jerry A. Holland, P.E., F.ACI; Cecil L. Bentley, Sr; Eldon (Tipp) G. Tipping, P.E., F.ACI; Rick E. Smith, F.ACI; and Bryan M. Birdwell**

There is an industry need to have a floor flatness and levelness testing specification that can be provided to the testing agency to direct how the testing is to be done and require the necessary communications that have to occur with all parties in order to produce a successful floor surface. This need is exacerbated due to the lack of industry standards regarding how the testing is to be performed, the absence of industry certifications for the personnel performing the testing, and the many industry misconceptions that have confused even otherwise knowledgeable testing agencies. Attached is a "complete" specification that can be provided to the testing agency concerning how to perform the testing and provide the detailed reporting and communication requirements that should occur with today's projects. The specification includes a flowchart that summarizes how the testing and communications with all parties should occur. Below we will try to clear up some of the more prevalent industry misconceptions concerning this testing, along with our commentary addressing some of the requirements in the specification.

Industry Misconceptions

Some of the industry misconceptions for floor flatness and levelness are the following:

1. The ASTM that directs how the F_F and F_L values are to be collected and calculated is ASTM E1155 - Standard Test Method for Determining F_F Floor Flatness and F_L Floor Levelness Numbers (Ref. 1). Many architectural and engineering firms just specify ASTM E1155 and think that is all that is required (and/or specify ACI 301 and ACI 117 – see discussion below), which is not correct. This ASTM E1155 primarily addresses how to calculate the F_F and F_L values but does not address how a test surface is to be divided into different test sections (other than a minimum sample measurement line length and area) nor does it address the specified overall values (SOV) or minimum local values (MLV). These items should be addressed in the project specification.
2. A single sample measurement line length is not sufficient to establish a local minimum value. MLV represent test section areas of the slab and therefore cannot be defined by results of a single line measurement. Unfortunately, papers that promote this misconception have been published with this misconception (Ref. 2); this information was later corrected by a letter to the editor along with other articles (Ref, 3 & 4).
3. Industry standards, such as ACI 301 (Ref. 5) and ACI 117 (Ref. 6), do not address how to divide the test surface (for SOV) into test sections (for MLV). This has caused some confusion because many have assumed this issue has been addressed in the industry standards. However, this issue of how many test sections in which to divide the test surface depends on the project budget, how much data is to be collected, and the schedule time to collect the data. Therefore, because this issue is project specific, this issue should be addressed in the project specifications. Below we discuss our requirements, which are based on a compromise between the amount of data one testing person can gather, while not affecting the construction schedule, but still providing sufficient localized data to minimize the amount of slab that would have to be removed and replaced if that test section did not meet the MLV.
4. ASTM E1155 and other industry standards do not specify the equipment accuracy for measuring the slab surface changes. The equipment accuracy should be stated in the project specifications.

Specification Commentary

The attached specification is based on many years of measuring and troubleshooting floor flatness and levelness issues on different types of projects. The following is commentary and background information regarding some of our specification requirements.

1. We have changed the definition of "test surface" from ASTM E1155's "entire floor" to "The entire day's of continuous concrete slab placement". Contractors have taken advantage of ASTM E1155's definition when placing slab portions with marginally low F_F/F_L values and then placing slabs with exceptionally high values of F_F/F_L, such that the average F_F/F_L will equal or exceed the SOV. This issue becomes more pronounced with large buildings, where a floor area as large as 1 million square feet or more might have significant slab areas with marginal MLV values of F_F/F_L. In our specification, by changing the definition of "test surface" this issue is minimized, especially with today's equipment where daily slab placements of 20,000 sf to 50,000 sf are common.

2. As mentioned above, there is no industry standard certification for personnel who perform the testing. We have seen the competency level of the testing personnel vary substantially; this includes some testing personnel who have "read the equipment manual" and rely on the software to do the testing correctly but have little fundamental understanding of the testing procedure. The major testing equipment manufacturers do provide certification training on how to operate their testing equipment and perform the testing. To have a minimum level of testing personnel competency, we have required the testing personnel to have attended and successfully completed the training provided by the manufacturer of their particular equipment and to submit their certification. In the future, we hope to encourage ACI to develop and offer a F-Number Certification Program and then require ACI Certified Technicians in ACI 301.

3. We have added additional reporting requirements above the ASTM E1155 minimal requirement of listing the F_F/F_L values in a tabular form. These requirements are necessary to help the contractor improve and troubleshoot issues when F_F/F_L values are low. These requirements are:

   A. Provide a floor plan showing the boundary limits of each test section, along with the locations of the sample measurement lines, such that the deficient areas can be located. The plan should be sufficiently accurate to allow the testing to be replicated and data to be verified if necessary.

   B. Provide a plot or graph of the sample measurement lines, along with the maximum *q* value (profile curvature value). This graph and *q* value can be used to determine if there are anomalies that are being "averaged out", with the result that acceptable F_F/F_L values are being reported even though localized problems may be present. Additionally, we take exception to ASTM E1155's two foot exclusion requirement for construction joints by requiring the sample measurement lines to start at the construction joint; we do this because these locations are often the worst portions of the slab due to different finishing tools and techniques and also because vehicles, personnel, etc. do not avoid these joints. By starting the sample measure lines at the construction joint, allows identification of potential construction joint elevation issues if they are occurring.

4. We have added a section concerning notifications. It is very important that the testing agency notify all of the parties if the MLV is not achieved for a specific test section. This notification is to occur immediately after the test for that section is completed. We have even provided a Work Flowchart showing how these notifications are to occur during the testing procedure and also the contractor's options if a test section is below the MLV. The contractor may choose to do additional testing to possibly limit the amount of slab that has to be removed and replaced.

5. We have required that the personnel who will perform the actual testing attend the slab pre-construction meeting. It is important that the testing personnel understand all aspects of the specification that affect the testing personnel's work, the importance of timely notifications if test sections MLV values are not being achieved, and who is to be notified.

6. We have required the test section dimensions to satisfy four different requirements and have provided a Test Section Boundary Example demonstrating these requirements. These requirements are based on a compromise between the amount of data one testing person can gather, while not affecting the construction schedule, and providing sufficient localized data to minimize the amount of slab that would have to be removed and replaced if that test section did not meet the MLV. Additionally, as noted in the Work Flowchart, the contractor may choose to do additional testing to further divide the deficient test section to possibly limit the amount of slab that has to be removed and replaced.

7. Slab finishing operations are typically performed parallel and perpendicular to column lines; this also includes the orientation of racking systems and vehicular traffic. Therefore, to evaluate any finishing issues with the testing data, we have required the sample measurement lines to be parallel and perpendicular to column lines and not diagonally oriented.

References:

1. ASTM E1155 – 14 Standard Test Method for Determining F_F Floor Flatness and F_L Floor Levelness Numbers
2. Cheek, M. A., 2011, “The Floor Flatness Report”, Concrete International, Jan., pp. 35-39.
3. Birdwell, B. M., and Darrow, D. L., 2012, “Letters”, Concrete International, Mar., p. 6.
4. ACI Staff, 2008, “Concrete Q&A: Rejecting Floors Based on One Sample Measurement Line”, Concrete International, Jul., pp. 83-84.
5. American Concrete Institute (ACI) 301-16 "Specifications for Structural Concrete".
6. American Concrete Institute (ACI) 117-10 "Specification for Tolerances for Concrete Construction and Materials and Commentary".

Wayne W. Walker, P.E., F.ACI, is a Principal and the Director of Engineering Services at **Structural Services, Inc.** He is on several ACI committees and has been a speaker at ACI seminars. He has also published other papers and has developed many computer programs to analyze and design slabs and other structures.

Jerry A. Holland, P.E., F.ACI, is a Principal, Vice-President and the Director of Design Services for **Structural Services, Inc.** He is on several ACI committees, teaches seminars for ACI and the World of Concrete. He has also published other papers and has more than 50 years of experience worldwide with the design, construction, and troubleshooting of concrete slabs other structures.

Cecil L. Bentley Sr. is a Concrete Construction Consultant for **Structural Services Inc.** He was the Owner and President of one of the Southeast’s largest concrete contractors. He is an examiner for the American Concrete Institute Concrete Flatwork Finisher/Technician Certification Program and a Specialty Commercial/Industrial Flatwork Finisher and Technician. Cecil has over 50 years of experience troubleshooting concrete failures.

Eldon (Tipp) G. Tipping, P.E., F.ACI, is a Principal, Vice-Chairman and Founder of **Structural Services Inc.** He is an industry leader, educator and a pioneer in developing placement, finishing, and monitoring procedures for flat work construction. He is on several ACI committees, teaches seminars for the World of Concrete and other organizations. Tipp has also published other papers and has more than 40 years of design and construction experience along with preforming many forensics investigations.

Rick E. Smith, F.ACI, is a Principal, President and a Senior Consultant for **Structural Services Inc.** He is a well-known industry leader concerning slabs-on-ground, suspended slabs and pavements. Rick has developed innovative designs related to the construction, maintenance, repair and polishing of slabs. He is on several ACI committees, teaches seminars for ACI and the World of Concrete.

Bryan M. Birdwell is a Principal, Senior Floor & Paving Consultant for **Structural Services Inc.** He is well-known in the concrete industry for his expertise in the installation, techniques and procedures of super flat and high tolerance floors. He is on several ACI committees and teaches seminars for the World of Concrete. Bryan is also an examiner for ACI's Specialty Commercial/ Industrial Concrete Flatwork Finisher/Technician Certification Program.

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SECTION 01 43 27 - RANDOM TRAFFIC AREAS FLOOR FLATNESS AND LEVELNESS TESTING

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes testing and reporting requirements for random traffic floor areas.

1.2 RELATED REQUIREMENTS

A. Section 03 30 00 - Cast-in-Place Concrete

B. Section 03 35 60 - Concrete Floor Finishing

1.3 REFERENCE STANDARDS

A. The referenced standards are to be the latest based on this Specification date as shown below.

1. ASTM E1155 - Standard Test Method for Determining F_F Floor Flatness and F_L Floor Levelness Numbers

1.4 DEFINITIONS

A. The definitions are to be per ASTM E1155, except as follows:

1. Test Surface: The entire day's of continuous concrete slab placement.
2. Test Section: The subdivision of the test surface where sample measurement lines are used to collect data for the slab's test surface.

B. Specified overall values (SOV): The composite values of all F-Numbers for the test sections of a test surface.

C. Minimum local values (MLV): The minimum F-Number values permitted for an individual test section.

1.5 SUBMITTALS

A. Evidence of Qualifications:

1. Provide a certificate verifying the person performing the work is a certified technician for the floor surface measuring equipment to be used.
2. Testing personnel to have a minimum of 3 years of floor surface testing experience. Submit list of 3 recently completed projects similar in complexity and include project address along with Architect, Structural Engineer, and Contractor's names and telephone numbers.

B. Equipment:

1. Provide floor surface measuring equipment data sheets.
2. Provide plan of action if floor surface measuring equipment is defective or inoperative.

C. Proposed test sections: After attending the Slab Pre-Construction Meetings and the submission of the contractor's slab placement plan, provide floor plan drawing showing the proposed test sections and sample measurement line locations for the concrete slab placements. Submit information a minimum of three days prior to slab placement.

D. Report requirements: The reports are to include as a minimum the following information:

1. The reporting requirements of ASTM E1155
2. Floor plan drawing showing the boundary limits of each test section with the sample measurement lines numbered and their locations identified on the plan. The plan should be sufficiently accurate to allow the testing to be replicated and data to be verified if necessary.
3. A plot of the slab surface profile elevation as a function of horizontal distance for each sample measurement line.
4. The listing of the maximum (+ or -) *q* value (profile curvature value) for each sample measurement line, along with the location.
5. Locations of floor test sections that are deficient are to be shown on the floor plan drawing.
6. The statistical amount of floor test surface area that is not in compliance with the specified SOV.

E. Report scheduling:

1. Submit written report by electronic means or hand deliver to parties concerned within 36 hours, or next regularly scheduled working day, after placement. Weekends and holidays are to be ignored when computing the testing and reporting deadlines. Include cost for retesting replaced or repaired defective areas.

    a. Retesting required because of non-conformance to specified requirements shall be performed by the same testing agency. Payment for retesting will be charged to the Contractor by deducting testing charges from the Contract Price.

F. Notifications:

1. Immediately notify preferably in less than 1 hour the Owner's representative and other parties concerned if any test section does not meet the MLV.
2. Immediately notify preferably in less than 1 hour the Owner's representative and other parties concerned if any test surface does not meet the SOV.
3. Complete testing, identify defective areas and give verbal report to Owner's representative and other parties concerned within 24 hours after placement.

1.6 QUALITY ASSURANCE

A. Testing Requirements:

1. Measure random traffic areas delineated on the drawings per ASTM E1155 with the following exceptions:

a. Sample measurement lines are to occur for floor areas within 2 feet of construction joints.

2. F-Number Requirements: As noted on drawings or specifications.
3. Owner's testing agency is neither authorized to change any specified requirement, approve any portion of Work, nor reject Work.
4. Responsibilities and duties of Contractor relative to Owner’s testing:

a. Notify Owner's testing agency in advance of slab’s pre-construction meeting to allow sufficient time to attend meeting.
b. Notify Owner's testing agency in advance of concrete placement to allow sufficient time to prepare for required testing.

5. Cost Responsibility: Costs for corrective work and extra testing required by defective work borne by Contractor.

B. Slab Pre-Construction Meetings:

1. Personnel who are to perform the actual testing and those who have authority to control Work are required to attend the slab’s pre-construction meetings.

PART 2 - PRODUCTS

2.1 EQUIPMENT

A. Floor surface measuring device is to be able to measure the floor surface elevation change over 12 in. with an accuracy tolerance that does not exceed +/- 0.002 in.

PART 3 - EXECUTION

3.1 GENERAL

A. Start testing sections as soon as possible as they become available after final troweling operations so as not to impede the slab curing process. The testing should be done sooner but shall not exceed 72 hours after completion of the slab concrete finishing operations for the area being tested.

B. For suspended slabs that have a specified F_L value, testing is to occur before removable forms and/or shores have been removed.

3.2 TEST SECTION DIMENSIONS

A. Test section areas are to satisfy all of the following:

1. A minimum of 5 test sections are to be used for a test surface that exceeds 2000 sf.
2. Conform to ASTM E1155 for the smallest permitted test section.
3. Test section is not to exceed 14,500 sf.
4. Test sections to be bound by construction joints, column or half-column lines.

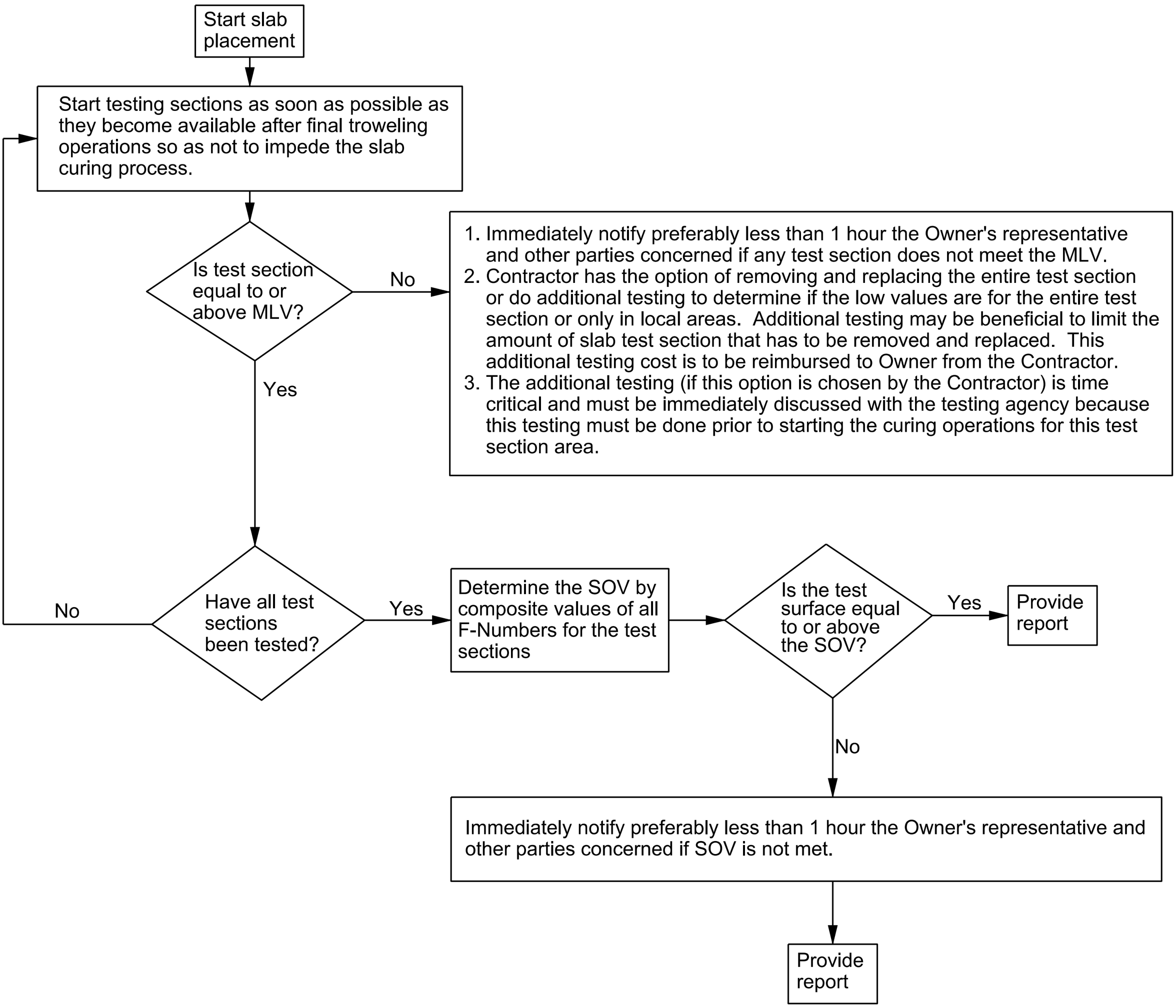
B. Orient sample measurement lines parallel and perpendicular to column lines, not diagonally oriented.

3.3 ATTACHMENTS

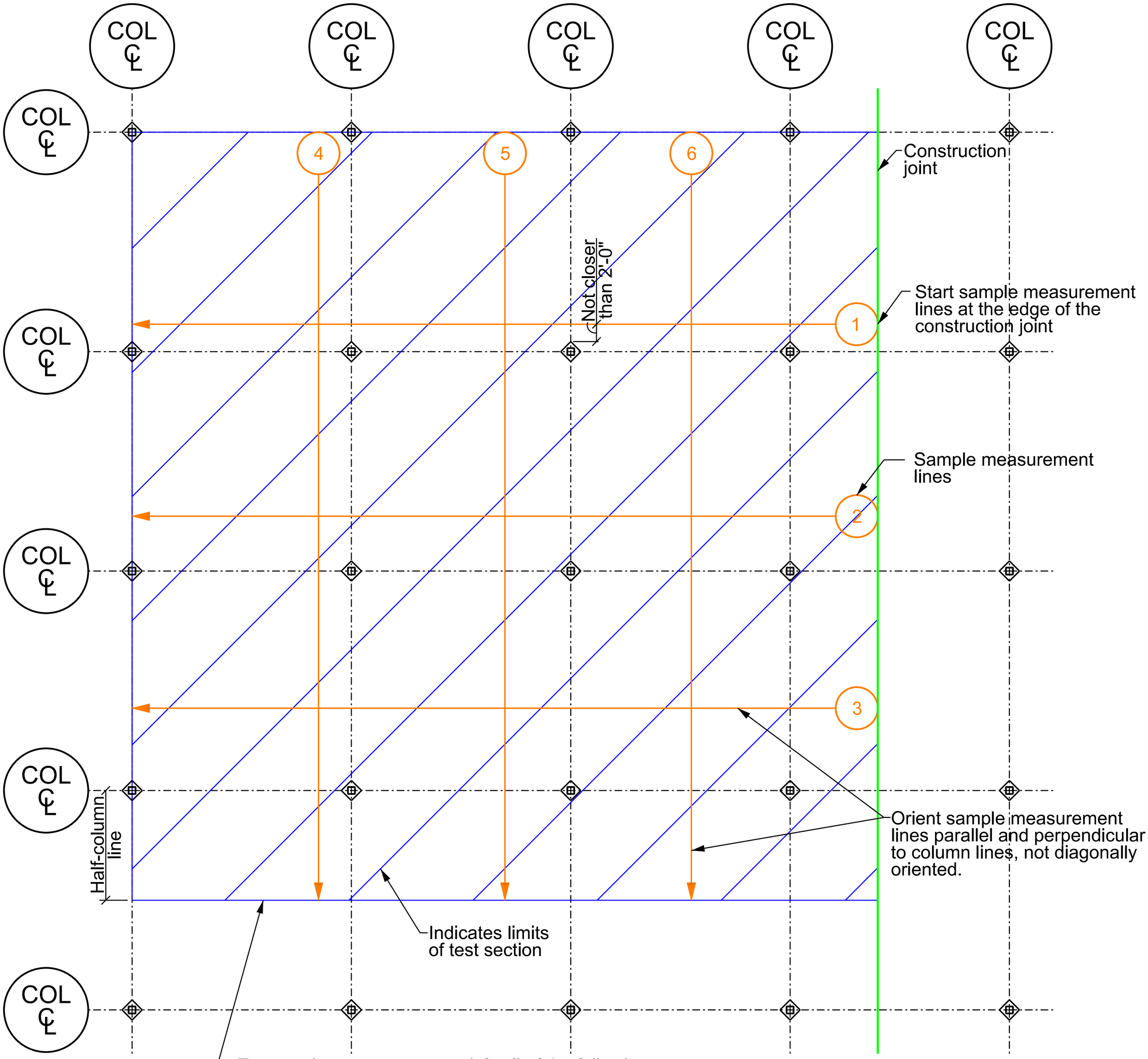
A. The following attachments are part of this Section:

1. Work Flowchart
2. Test section boundary example

End of Section



WORK FLOWCHART



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TEST SECTION BOUNDARY EXAMPLE