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DATA COLLECTION, MATERIAL TESTING AND CONDITION ASSESSMENT REQUIREMENTS FOR EXISTING CONCRETE BUILDINGS

This Information Bulletin establishes the required protocol for investigation of as-built conditions, data collection, and material testing and condition assessments for an existing concrete buildings. The data obtained from available drawings, specifications, inspection records and testing as outlined here shall be used for evaluation and/or analysis of the existing concrete buildings.

I. BACKGROUND

As-built conditions and material properties of building elements are required in order to properly characterize building performance in seismic analysis. In order to make sound engineering assumptions and judgments, an engineer shall either obtain the existing building construction documents and records and/or perform appropriate condition assessment and material testing to establish the properties of building structural components. A preliminary review should identify the gravity and lateral-force-resisting elements and systems, and their critical components and connections. When complete as-built drawings and prior testing records are not available, the engineer shall perform a thorough investigation of the building gravity and lateral-load-resisting systems.

This bulletin was developed based on data collection and testing protocols in ASCE 41-17. However, it can also be used when analyzing the building using ASCE 7-16.

II. DEFINITIONS

Coefficient of Variation – the ratio of the standard deviation to the mean value of a specific material property based on a number of tests.

Comprehensive – a more in depth level of assessment of the Lateral Force Resisting System, which may include removal of finishes or, for concrete structures, local minimized removal of concrete cover to observe steel reinforcing.

Comprehensive Data Collection - a minimum level of testing to confirm material strengths and properties that is used when there is little or no knowledge of material properties or when the building is being analyzed for greater than Life Safety performance level.

Expected Properties –the mean tested value of when testing is performed. Expected material properties are used to check deformation controlled actions.

Exposure – local minimized removal of cover concrete and other materials to inspect reinforcing system details.

Lower Bound Properties – Defined as either the listed default property, nominal material value from construction documents or specifications, or the mean minus one standard deviation when material testing is performed. Lower bound material properties are used to check force-controlled actions.

Material Properties – the strength and stiffness properties of the building material.

Nominal Properties – material properties specified in the construction documents, if available, which shall be taken as lower-bound material properties.

Testing – laboratory testing of material samples taken from a structure to determine in –place mechanical properties of materials and components of the Lateral Force Resisting System.

Usual Data Collection – a minimum level of testing to confirm material strengths and properties that is used when there is little to no knowledge of material properties and the building is being analyzed for a Life Safety or lower performance level.

Visual – a direct visual inspection of representative primary seismic components and connections.

III. CONDITION ASSESSMENT AND MATERIAL TESTING PROTOCOL

The condition assessment and material testing requirements shall be per Flowchart 1 and Tables 1 and 2.

A. Condition Assessment

Condition assessment of existing building and site conditions shall be performed and shall include the following:

1. Examination of the physical condition of primary and secondary components, and the presence of any degradation.
2. Verification of the presence and configuration of components and their connection, and the continuity of load paths between components, elements, and systems,
3. A review and documentations of other conditions, including neighboring party walls and buildings presence of non-structural components and mass, and prior remodeling,
4. Collection of information needed to select a knowledge factor
5. Confirmation of component orientation, plumbness, and physical dimensions.

ASCE 41-17 Section 10.2.3.2 provides two types of condition assessments: Visual Condition Assessment and Comprehensive Condition Assessment.

Visual Condition Assessment

For Visual Condition Assessment, a representative sampling of at least 20% of the components and connections shall be visually inspected at each floor level. If significant damage or degradation is found, the assessment sample of all similar type critical components in the building shall be increased to 40% or more, as necessary, to accurately assess the performance of components and connection with degradations.

Comprehensive Conditions Assessment

For Comprehensive Conditions Assessment, if detailed design drawings exist, exposure of at least three different primary connections shall occur to verify that there are no deviations or consistent deviations from the drawings. If inconsistent deviations are noted, then at least 25% of the specific connection type shall be inspected to identify the extent of deviation.

In the absence of detailed design drawings, at least three connections of each primary connection type shall be exposed for inspection. If common detailing among the three connections is observed, it shall be permitted to consider this condition as representative of installed conditions. If variations are observed among like connections, additional connections shall be inspected until an accurate understanding of building construction is gained.

B. Material Testing Protocol

Material Properties:

The following component and connection material properties shall be obtained for the as-built building:

1. Concrete compressive strength, and
2. Yield and ultimate strength of nonprestressed and prestressed steel reinforcement, cast-in-place and post installed anchors, and metal connection hardware.

Expected material properties shall be based on mean values of tested material properties. Lower bound material properties shall be based on mean values of tested material properties minus one standard deviation, σ.

Nominal material properties, or properties specified in construction documents, shall be taken as lower-bound material properties. Corresponding expected material properties shall be calculated by multiplying lower-bound values by a factor taken from Table 10-1 of ASCE 41-17 to translate from lower-bound to expected values

Table 10-1. Factors to Translate Lower-Bound Material Properties to Expected Strength Material Properties

Material Property	Factor
Concrete compressive strength	1.50
Reinforcing steel tensile and yield strength	1.25
Connector steel yield strength	1.50

Component Properties

The following component properties and as built conditions shall be established:

1. Cross-sectional dimensions of individual components and overall configuration of the structure;
2. Configuration of component connections, size, embedment depth, type of anchors, thickness of connector material, anchorage and interconnection of embedments, and the presence of bracing or stiffening components;
3. Modification to components or overall configuration of the structure;
4. Most recent physical condition of components and connections, and the extent of any deterioration;
5. Deformations beyond those expected because of gravity loads, such as those caused by settlement or past earthquake events; and
6. Presence of other conditions that influence building performance, such as nonstructural components that can interact with structural components during earthquake excitation.

Test Methods to Quantify Material Properties

When determining material properties with the removal and testing of samples for laboratory analysis, sampling shall take place in primary gravity- and seismic-force-resisting components in regions with the least stress.

For concrete material testing, the sampling program shall include the removal of standard cores. Core drilling shall be preceded by nondestructive location of the reinforcing steel, and core holes should be located to avoid damage to or drilling through the reinforcing steel. Core holes shall be filled with concrete or grout of comparable strength having non-shrinkage properties. If conventional reinforcing steel is tested, sampling shall include removal of local bar segments and installation of replacement spliced material to maintain continuity of the reinforcing bar for transfer of bar force unless an analysis confirms that replacement of the original components is not required.

Removal of core samples and performance of laboratory destructive testing shall be permitted to determine existing concrete strength properties. Removal of core samples shall use the procedures specified in ASTM C42. Testing shall follow the procedures contained in ASTM C42, ASTM C39, and ASTM C496. Core strength shall be converted to in-place concrete compressive strength by an approved procedure.

Removal of bar or tendon samples and performance of laboratory destructive testing shall be permitted to determine existing steel reinforcement strength properties. The tensile yield and ultimate strengths for reinforcing and prestressing steels shall follow the procedures included in ASTM A370. Reinforcing samples that are slightly damaged during removal are permitted to be machined to a round bar as long as the tested area is at least 70% of the gross area of the original bar. Prestressing materials shall meet the supplemental requirements in ASTM A416, ASTM A421, or ASTM A722, depending on material type. Properties of connector steels shall be permitted to be determined by wet and dry chemical composition tests and direct tensile and compressive strength tests as specified by ASTM A370. Where strength, construction quality for either anchors or embedded connectors are required, in-place testing shall satisfy the provisions of ASTM E488-96.

Data Collection

Materials testing is not required if material properties are available from original construction documents that include material test records or reports. Material test records or reports shall be representative of all critical components of the building structure.
Data collection from material tests is classified as either comprehensive or usual.

Usual Data Collection

The minimum number of tests required to determine concrete and reinforcing steel material properties for usual data collection shall be based on the following criteria:

1. If the specified design strength of the concrete is known, at least one core shall be taken from samples of each different concrete strength used in the construction of the building, with a minimum of three cores taken for the entire building;
2. If the specified design strength of the concrete is not known, at least one core shall be taken from each type of seismic-force-resisting component, with a minimum of six cores taken for the entire building;
3. If the specified design strength of the reinforcing steel is known, nominal or specified material properties shall be permitted without additional testing; and
4. If the specified design strength of the reinforcing steel is not known, at least two strength test coupons of reinforcing steel shall be removed from the building for testing.

Comprehensive Data Collection

Coefficient of Variation

A minimum of three tests shall be conducted to determine any property. If the coefficient of variation exceeds 20%, additional tests should be performed until the coefficient of variation is equal to or less than 20%. In determining coefficient of variation, cores shall be grouped by grades of concrete and element type. The number of tests in a single component shall be limited so as not to compromise the integrity of the component.

Concrete Materials

For each concrete element type, a minimum of three core samples shall be taken and subjected to compression tests. A minimum of six total tests shall be performed on a building for concrete strength determination. If varying concrete classes or grades were used in the building construction, a minimum of three samples and tests shall be performed for each class and grade. The modulus of elasticity and tensile strength shall be permitted to be estimated from the compressive strength testing data. Samples shall be taken from components, distributed throughout the building, that are critical to the structural behavior of the building.

Tests shall be performed on samples from components that are identified as damaged or degraded to quantify their condition. Test results from areas of degradation shall be compared with strength values specified in the construction documents. If test values less than the specified strength in the construction documents are found, further strength testing shall be performed to determine the cause or identify the degree of damage or degradation.

The minimum number of tests to determine compressive strength of each concrete element type shall conform to one of the following criteria:

1. For concrete elements for which the specified design strength is known and test results are not available, a minimum of three core tests shall be conducted for each floor level, 400 yd^3 of concrete, or 10,000 ft^2 of surface area, whichever requires the most frequent testing; or

2. For concrete elements for which the design strength is unknown and test results are not available, a minimum of six core tests shall be conducted for each floor level, 400 yd^3 of concrete, or 10,000 ft^2 of surface area, whichever requires the most frequent testing. Where the results indicate that different classes of concrete were used, the degree of testing shall be increased to confirm class use.

3. Alternatively, for concrete elements for which the design strength is known or unknown and test results are not available, it is permitted to determine the lower-bound compressive strength according to the provisions in Section 6.4.3 of ACI 562-16. If the lower-bound compressive strength is determined in this manner, the expected compressive strength shall be determined as the lower-bound compressive strength value obtained from ACI 562-16, Eq. 6.4.3 plus one standard deviation of the strength of the core samples. When following the provisions in Section 6.4.3 of ACI 562-16, the minimum number of samples per element type shall be four. The sample locations shall be:

    a. Distributed to quantify element material properties throughout the height of the building, and
    b. Distributed to quantify element material properties in locations critical to the structural system being investigated.

Nonprestressed Reinforcement and Connector Steels

Tests shall be conducted to determine both yield and ultimate strengths of reinforcing and connector steel. Connector steel is defined as additional structural steel or miscellaneous metal used to secure precast and other concrete shapes to the building structure. A minimum of three tensile tests shall be conducted on conventional reinforcing steel samples from a building for strength determination, subject to the following supplemental conditions:

1. If original construction documents defining properties exist, then at least three strength coupons shall be randomly removed from each element or component type and tested; or
2. If original construction documents defining properties are unavailable, but the approximate date of construction is known and a common material grade is confirmed, at least three strength coupons shall be randomly removed from each element or component type for every three floors of the building; and
3. If the construction date is unknown, at least six strength coupons for every three floors shall be performed.

Prestressing Steels

Sampling prestressing steel tendons for laboratory testing shall only be performed on prestressed components that are part of the seismic-force-resisting system. Prestressed components in diaphragms shall be permitted to be excluded.

Tendon or prestress removal shall be avoided if possible. Any sampling of prestressing steel tendons for laboratory testing shall be done with extreme care. Determination of material properties may be possible, without tendon or prestress removal, by careful sampling of either the tendon grip or the extension beyond the anchorage, if sufficient length is available.
All sampled prestressed steel shall be replaced with new, fully connected, and stressed material and anchorage hardware, unless an analysis confirms that replacement of original components is not required.

Knowledge Factor

To account for uncertainty in the collection of as-built data, a knowledge factor, k, shall be selected from Tables 1 and 2 of this document on individual component basis, as determined by the level of knowledge obtained for that component during the data collection. Table 1 provides the testing requirements for Concrete component. Table 2 provides the testing requirements for Reinforcing Steel Material. The knowledge factor, k, shall be lesser of the values obtained from Tables 1 and 2 and shall be applied to determine component capacities as specified in Chapter 7 of ASCE 41-17. Similarly, if ASCE 7-16 is used, reduction factor, K, shall be used when calculating the component capacity.

C. Plan Submittal and Testing Result Summary Requirements

The submitted plans shall contain material testing result summary for each required structural components which identifies the following information.

- Required and proposed number of tests for each required structural component
- Coefficient of Variation (COV)
- Upper bound strength
- Lower bound strength
- Allowed and proposed “k” factor for each type of required structural component

The plans shall specify the test locations (vertical & horizontal) and types of testing for each structural component. Also, they shall identify the types and locations (with pictures) of detected structural deficiencies per condition assessment section, as well as, proposal corrective actions for each such structural deficiencies

The Building Structural Engineer of Record shall confirm and accept qualifications of material testing agency, including but not limited to field test/sample collecting agency and laboratory testing agency. The testing and collecting agencies shall be certified by the Los Angeles Department of Building and Safety, as testing agencies.

Flowchart 1
Data Collection for Concrete
Condition Assessment and Material Testing Requirements

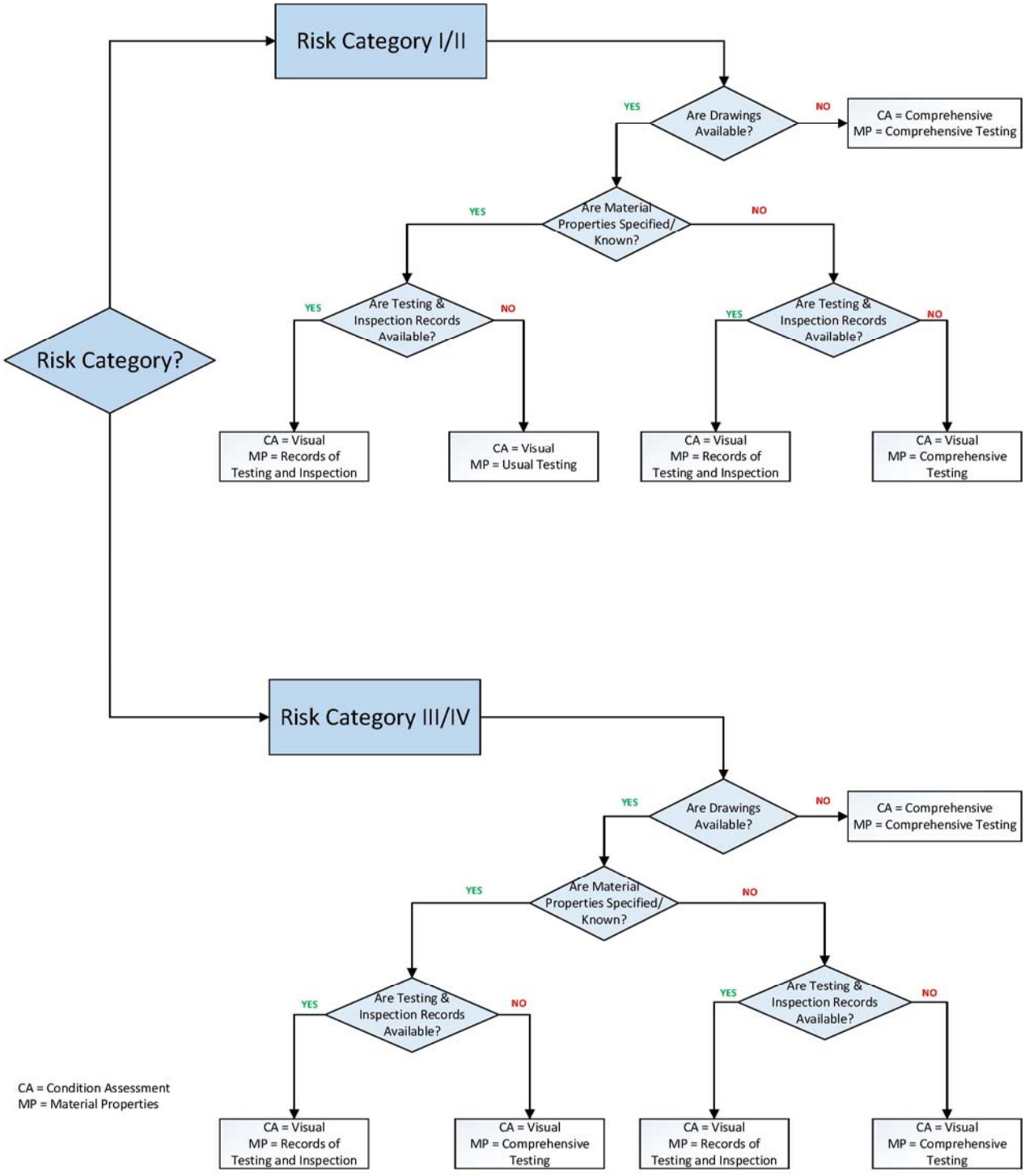

Table 1
Concrete Testing Requirements

Performance Level	Available Information			Level of Testing Performed	Minimum Number of Tests Required	Test Results	Expected Strength	Lower- Bound Strength	Knowledge Factor (k)
	Drawings	Material Properties	Inspection and Testing Records						
Risk Category I/II	Drawings are available	Properties are specified	Inspection / Testing Records are available	No Testing	N/A	N/A	Corresponding specified strength x (1.5) factor	Corresponding specified strength	k=1.0 (Table 6-1)
			Inspection/Testing Records are not available	Usual Testing	(1) Core tests for each different concrete strength, with minimum of (3) cores taken from the entire building	Less than specified expected strength	Mean Tested Value	Mean Tested Value - Std Dev	k=1.0 (Table 6-1)
						Greater than specified expected strength	Corresponding specified strength x (1.5) factor	Corresponding specified strength	k=1.0 (Table 6-1)
		Properties are not specified	Inspection / Testing Records are available	No Testing	N/A	N/A	Corresponding specified strength x (1.5) factor	Corresponding specified strength	k=1.0 (Table 6-1)
			Inspection/Testing Records are not available	Comprehensive Testing	(3) Core tests for each floor level, 400 cy of contrete, or 10,000 sq ft or surface area, whichever requires the most frequent testing.	COV<20%	Mean Tested Value	Mean Tested Value - Std Dev	k=1.0 (Section 10.2.4)
						COV>20%	Mean Tested Value	Mean Tested Value - Std Dev	K=0.75 (Section 10.2.4)
	Drawings are not available	Properties are not specified	Inspection Records are not available	Comprehensive Testing	(6) Core tests for each floor level, 400 cy of contrete, or 10,000 sq ft or surface area, whichever requires the most frequent testing.	COV<20%	Mean Tested Value	Mean Tested Value - Std Dev	k=1.0 (Section 10.2.4)
						COV>20%	Mean Tested Value	Mean Tested Value - Std Dev	K=0.75 (Section 10.2.4)
Risk Category III/IV	Drawings are available	Properties are specified	Inspection / Testing Records are available	No Testing	N/A	N/A	Corresponding specified strength x (1.5) factor	Corresponding specified strength	k=1.0 (Table 6-1)
			Inspection/Testing Records are not available	Comprehensive Testing	(3) Core tests for each floor level, 400 cy of contrete, or 10,000 sq ft or surface area, whichever requires the most frequent testing.	COV<20%	Mean Tested Value	Mean Tested Value - Std Dev	k=1.0 (Section 10.2.4)
						COV>20%	Mean Tested Value	Mean Tested Value - Std Dev	K=0.75 (Section 10.2.4)
		Properties are not specified	Inspection / Testing Records are available	No Testing	N/A	N/A	Corresponding specified strength x (1.5) factor	Corresponding specified strength	k=1.0 (Table 6-1)
			Inspection/Testing Records are not available	Comprehensive Testing	(6) Core tests for each floor level, 400 cy of contrete, or 10,000 sq ft or surface area, whichever requires the most frequent testing.	COV<20%	Mean Tested Value	Mean Tested Value - Std Dev	k=1.0 (Section 10.2.4)
						COV>20%	Mean Tested Value	Mean Tested Value - Std Dev	K=0.75 (Section 10.2.4)
	Drawings are not available	Properties are not specified	Inspection Records are not available	Comprehensive Testing	(6) Core tests for each floor level, 400 cy of contrete, or 10,000 sq ft or surface area, whichever requires the most frequent testing.	COV<20%	Mean Tested Value	Mean Tested Value - Std Dev	k=1.0 (Section 10.2.4)
						COV>20%	Mean Tested Value	Mean Tested Value - Std Dev	K=0.75 (Section 10.2.4)

Table 2
Reinforcing Steel Material Testing Requirements

Performance Level	Available Information			Level of Testing Performed	Minimum Number of Tests Required	Test Results	Expected Strength	Lower- Bound Strength	Knowledge Factor (k)
	Drawings	Material Properties	Inspection and Testing Records						
Risk Category I/II	Drawings are available	Properties are specified	Inspection / Testing Records are available	No Testing	N/A	N/A	Specified Value x (1.25) Factor	Specified Value	k=1.0 (Table 6-1)
			Inspection/Testing Records are not available	No Testing	N/A	N/A	Specified Value x (1.25) Factor	Specified Value	k=0.9 (Table 6-1)
		Properties are not specified	Inspection / Testing Records are available	No Testing	N/A	N/A	Specified Value x (1.25) Factor	Specified Value	k=1.0 (Table 6-1)
			Inspection/Testing Records are not available	Usual Testing	(2) Strength test coupons of reinforcing steel shall be removed from the building for testing	N/A	Average Tested Value	Average Tested Value / (1.25) factor	k=1.0 (Table 6-1)
	Drawings are not available	Properties are not specified	Inspection Records are not available	Comprehensive Testing	(3) Strength coupons shall be randomly removed from each element or component type for every three floors of the building	COV<20%	Mean Tested Value	Mean Tested Value - Std Dev	k=1.0 (Section 10.2.4)
						COV>20%	Mean Tested Value	Mean Tested Value - Std Dev	K=0.75 (Section 10.2.4)

Performance Level	Available Information			Level of Testing Performed	Minimum Number of Tests Required	Test Results	Expected Strength	Lower- Bound Strength	Knowledge Factor (k)
	Drawings	Known Information	Inspection and Testing Records						
Risk Category III/IV	Drawings are available	Properties are specified	Inspection / Testing Records are available	No Testing	N/A	N/A	Specified Value x (1.25) Factor	Specified Value	k=1.0 (Table 6-1)
			Inspection/Testing Records are not available	Comprehensive Testing	(3) Strength coupons shall be randomly removed from each element or component type for every three floors of the building	COV<20%	Mean Tested Value	Mean Tested Value - Std Dev	k=1.0 (Section 10.2.4)
						COV>20%	Mean Tested Value	Mean Tested Value - Std Dev	K=0.75 (Section 10.2.4)
	Drawings are not available	Date of Construction is know	Inspection / Testing Records are available	No Testing	N/A	N/A	Specified Value x (1.25) Factor	Specified Value	k=1.0 (Table 6-1)
			Inspection/Testing Records are not available	Comprehensive Testing	(3) Strength coupons shall be randomly removed from each element or component type for every three floors of the building	COV<20%	Mean Tested Value	Mean Tested Value - Std Dev	k=1.0 (Section 10.2.4)
						COV>20%	Mean Tested Value	Mean Tested Value - Std Dev	K=0.75 (Section 10.2.4)
		Date of Construction is not know	Inspection Records are not available	Comprehensive Testing	(6) Strength coupons for every three floors	COV<20%	Mean Tested Value	Mean Tested Value - Std Dev	k=1.0 (Section 10.2.4)
						COV>20%	Mean Tested Value	Mean Tested Value - Std Dev	K=0.75 (Section 10.2.4)