Ultrasonic	To detect cracks, voids, porosities, laps, poor brazing and bounding, and segregated inclusions including flaws too small to be detected by other methods.	Ultrasonic waves are applied to the surface of metal. The waves will propagate in the metal and will be reflected by any discontinuity or change in density. The reflected echo is analyzed to locate internal flaws and cracks.	High; for development of test procedures, operation and interpretation of results.	Nondestructive; portable; locates very small surface and subsurface discontinuities; instant results; accurate measure of thickness. Because of good penetration can be used to inspect thick objects. Extremely small flaws can be detected.	Sensitivity is reduced by rough surface; odd shape samples are hard to analyze; requires skilled operator. Depends on orientation of defects and operator's ability to interpret results. Must couple transducer to surface of specimen carefully. Permanent record is not obtained. Referenced standards may be needed for calibration of equipment and for interpretation of results.	2, 10, 11, 12, 13, 15, 16, 19, 20
Visual	To evaluate surface condition. To check dimensional accuracy. To detect corrosion, cracks, voids, fabricating discontinuities, weld undercuts and overlaps, pits and other surface irregularities. To evaluate condition of connections and connectors, missing or loose bolts, slag inclusions, unwelded and poor weld appearances.	A visual examination of surface condition of metals can be performed by naked eye or by the use of special devices such as magnifiers, borescope, fiber-optic, flashlight, weld gauge, and panoramic camera. Magnifiers can be used to detect small flaws and cracks.	Experience and expertise is required for thorough inspection and detection of flaws.	Nondestructive; simple; inexpensive; portable; large amount of data on surface condition and overall appearance of members can be obtained. Can be used to locate problem areas. Hidden surfaces can be inspected using special devices. Should be used in any evaluation even if other more powerful methods of testing are used.	Basically qualitative information is obtained. Little quantitative measurements can be made. Only surface condition can be evaluated. Some permanent records can be obtained by photography and recording the condition.	9, 14

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TABLE 3.7.9. Test Methods for Determining Physical Properties of Masonry Units and Masonry Assemblages on Masonry Specimens

Property	Purpose of Test	Test Method	User Expertise	Advantages	Limitations	References
Absorption	Determination of the percentage of absorption by mass of brick, tile and concrete masonry units and of natural building stone.	Determination of both dry and saturated mass.	Standard laboratory test. Moderate expertise required.	Easy test, low cost.	Specimens must be taken from structure for testing. Results are affected by mortar clogging pores.	3, 4, 5, 6, 7, 8, 9, 10, 15, 16, 18, 19, 20, 23, 24, 25, 26, 27, 47
Bulk specific gravity	Determination of bulk specific gravity of natural building stone.	Determination of weights of dried specimen, soaked and surface dried specimen and of soaked specimen in water.	Standard laboratory test. Moderate expertise required.	Easy test, low cost.	Specimens must be taken from structure for testing.	10, 22, 23, 24, 25
Compressive strength	Determination of compressive strength of brick, tile and concrete masonry units and natural building stone.	Specimens of masonry units or stone are capped and tested in a testing machine using standard procedures.	For test on specimens, standard laboratory tests. Moderate expertise required.	Easy tests, low cost.	Test specimens must be taken from structure for testing.	3, 4, 5, 6, 7, 8, 9, 14, 15, 16, 17, 18, 19, 23, 24, 25, 26, 27, 30, 38
Compressive strength (in situ)	Compressive strength of masonry, in situ	In situ tests involve installation of flatjack device in saw-cut mortar joints.	For in situ tests, moderate expertise required.	In situ test possible.	For in situ tests, estimated stress restricted to width of flatjack.	33
Concentrated load	Determination of the concentrated loads that can be supported by masonry assemblages.	Determination of average compressive stress on unreinforced solid-unit masonry by loading.	Specialized expertise required.	In situ test possible.	Special jigs required. Expensive.	37
Deformability	Determination of the deformability of masonry assemblages.	In situ test involving installation of flatjack device in saw-cut mortar joints.	Low degree of expertise required.	Easy test.	Relatively nondestructive.	34
Durability (See also freezing and thawing)	Determination of durability of brick masonry as measured by compressive strength, absorption and saturation coefficient.	Standard tests for compressive strength, absorption and saturation coefficient.	Standard laboratory tests. Moderate expertise required.	Easy tests, low cost.	Specimens must be taken from structure for testing. Results may be misleading. Freezing and thaw test may provide better results.	6, 7, 8, 19, 27

TABLE 3.7.9. Test Methods for Determining Physical Properties of Masonry Units and Masonry Assemblages on Masonry Specimens (*Continued*)

Property	Purpose of Test	Test Method	User Expertise	Advantages	Limitations	References
Efflorescence	Determination of leaching of soluble salts in brick masonry units.	Specimens are immersed in distilled water then oven dried, inspected and rated.	Standard laboratory test. Low degree of expertise required.	Easy test, low cost.	False results possible since units are contaminated in the wall.	19, 27
Flexure strength	Determination of flexural strength of building stone.	Simple beam testing using quarter point loading.	Standard laboratory test. Moderate expertise required.	Useful because it indicates differences in flexural strength between different building stones.	Fairly long sample (ten times depth) required to be taken from structure.	24, 29
Flexural tensile strength	Determination of tensile strength that can be supported by masonry assemblages.	Determination of average flexural tensile strength of unreinforced solid-unit masonry by loading.	Specialized expertise required.	In situ test possible.	Special jigs required. Expensive.	32, 37, 41
Freezing and thawing	Determination of resistance of brick masonry units to rapidly repeated cycles of freezing and thawing.	Test specimens under controlled moisture conditions are subjected to standard cycles of freezing and thawing. Specimens are measured for mass before and after tests and percent changes recorded.	Standard laboratory tests. Moderate expertise required.	Provides useful information.	Specimens must be taken from structure for testing. Requires 10 weeks to complete test.	6, 7, 8, 19, 27, 29, 35
Initial rate of absorption	Determination of initial rate of absorption of brick masonry units and slate.	Specimens are dried, set in water for 1 min, and mass determined. Gain in mass is recorded.	Standard laboratory test. Moderate expertise required.	Important information to determine loss of mixing water in mortar and hence water tightness of joints.	Specimens must be taken from structure for testing.	6, 7, 8, 13, 19, 26, 27
Modulus of rupture and secant modulus of rupture	Determination of modulus of rupture of natural building stone and of brick masonry units and modulus of rupture and secant modulus of rupture of masonry assemblage.	Specimens are tested as beam with midspan loading and tested to failure. Modulus of rupture calculated from breaking load.	Standard laboratory test. Moderate expertise required.	Test indicates differences between various specimens. ASTM E72 and E519 can be adapted to in situ tests.	Specimens must be taken from structure for testing.	7, 8, 11, 12, 20, 23, 24, 25, 26, 37, 42

Saturation	Determination of saturation coefficient of brick masonry units.	Same procedure as for determining absorption except saturated mass after 24 h and 5 h boiling are used in calculation.	Standard laboratory test. Low degree of expertise required.	Saturation coefficient used as measure of durability.	Specimens must be taken from structure for testing. Results may be misleading.	6, 7, 19, 27
Shear strength	Determination of shear strength that can be supported by masonry assemblages.	Determination of average shear strength in unreinforced solid-unit masonry by loading.	Specialized expertise required.	ASTM E72 and E519 can be adapted to in situ test. UBC 21-6 is an in situ test.	Special jigs required. Expensive. UBC 21.6 has limited use.	30, 37, 42, 46
Splitting tensile strength	Determination of splitting tensile strength of masonry units. Can also be used to detect the presence of defects.	Compressive load is applied to the unit by means of bearing rods resulting in a tensile stress distributed over the height of the unit.	Specialized expertise required.	Laboratory method to determine physical properties of masonry.	Precision of test method not very good. Currently, seldom used to determine physical properties.	31
Strength of anchors	Determination of static, tensile and shear strength of post-installed and cast-in-place anchorage systems in structural masonry.	Loading plates are located at anchors to be tested and appropriate testing equipment and testing system used to determine strength of anchor.	Special jigs must be constructed to mount on to anchors in structure. Specialized expertise required.	In situ strength values of anchorage determined.	While specimens are not removed from structure, tests are destructive.	39, 43
Tensile load	Determination of tensile load that can be supported by masonry assemblages.	Determination of average tensile load of unreinforced solid unit masonry by loading.	Specialized expertise required.	ASTM E72 can be adapted to in situ test.	Special jigs required. Expensive.	30, 37, 41
Transverse load	Determination of transverse load that can be supported by masonry assemblages.	Determination of average transverse load on unreinforced solid unit masonry by loading.	Specialized expertise required.	ASTM E72 can be adapted to in situ test.	Special jigs required. Expensive.	30, 37, 41
Water penetration	Determination of resistance to water penetration of masonry assemblages.	Test chambers are placed against specimens with controlled temperature and humidity conditions. Water is applied with increased air pressure. Dampness on back of specimen observed.	Standard laboratory test. Specialized expertise required.	Provides useful information on quality of material coatings, leakage and workmanship.	Water penetration is significantly affected by air pressure in test chamber. ASTM E514 intended for laboratory use.	40, 45

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TABLE 3.7.10. NDT Methods for Determining Properties and Physical Conditions of Masonry Units and Masonry Assemblages

Test Method	Purpose of Test	Principle of Operation	User Expertise	Advantages	Limitations	References
Acoustic impact (Hammer test)	Detect delaminations or disbonds in composite systems; detect voids and cracks in materials, e.g., hammer technique to detect defective masonry units.	Surface of object is struck with a hammer (usually metallic). The frequency and damping characteristics of the "ringing" can indicate the presence of defects.	Low level of expertise required to use, but experience needed for interpreting results.	Portable; easy to perform test; electronic measuring equipment not needed for qualitative results.	Geometry and mass of test object influences results; poor discrimination; reference standards required for electronic testing.	17, 35, 37
Electrical resistance probe	Measure of moisture migration patterns in masonry walls.	Electrical resistance between two probes inserted into test component is measured. The resistance decreases with increased moisture content.	Low.	Equipment is inexpensive, simple to operate, and many measurements can be rapidly made.	Not reliable at high moisture content; precise results are not usually obtained.	Table 3.7.3, 17
Flatjack	Determination of in situ stresses and deformability.	A portion of a mortar joint is removed, and a flatjack installed in the slot. Deformations are measured before the slot is cut and the jack pressure required to restore deformation.	Moderate expertise required.	Can determine stress in wall in cases where loadings or displacements are unknown or difficult to quantify. High reliability.	Numerous measurements are required to obtain a full picture of deformation and stress. Usually only one face of masonry wall is accessible.	9, 15, 24, 25, 29, 35
Fiber optics (probe holes with fiberscope)	Check condition of materials in cavity, such as thermal insulation, pipes, and electrical wiring installed in wall cavities; check for unfilled cores in reinforced masonry construction; check for voids along grouted stressed tendons.	Bundle of flexible, optical fibers with lens and illuminating systems is inserted into small bore holes thus enabling view of interior of cavities.	Low.	Direct visual inspection of otherwise inaccessible parts is possible.	Probe holes usually must be drilled; probe holes must connect to a cavity.	Table 3.7.3, 35

Gamma radiography	Locates internal cracks, voids and variations in density and composition of materials. Locating internal parts in a structural component, e.g., reinforcing steel in masonry.	Gamma radiation attenuates when passing through a structural component. Extent of attenuation controlled by density, and thickness of materials of the structural component. Photographic film record usually made and analyzed.	High level of expertise.	Portable and relatively inexpensive compared to X-ray radiography; internal defects can be detected; applicable to a variety of materials.	Radiation intensity cannot be adjusted; long exposure times may be required; dangerous radiation; two opposite surfaces of component must be accessible. A special license is required to obtain gamma isotope sources.	3, 7, 10, 17, 19, 25, 35, 37
Physical measurements	Physical documentation of observed or suspected conditions observed visually.	Physical measurement of alignment, crack size and location, differential settlement of structure, deflections, displacement and distortion by means of surveying tools and instruments.	Moderate level of expertise required in use of surveying equipment. Expertise needed for interpretation of results.	Easy to perform. No special equipment. Low cost.	Physical access required. This may require scaffolding and could be costly.	12
Ultrasonic pulse velocity	Internal discontinuities can be located and their size estimated.	Operates on principle that vibrational wave propagation is affected by quality of masonry; pulse waves are induced in materials and those reflected back are detected; both the transmitting and receiving transducers usually are contained in the same probe.	High level of expertise required to interpret results. Low level of expertise required to make measurements.	Excellent for rapid surveys of large areas.	Good coupling between transducer and test substrates critical; interpretation of results can be difficult; density and amount of aggregate may affect results; calibration standards required.	1, 7, 17, 18, 20, 22, 25, 26, 27, 29, 31, 35, 37, 38
Visual examination	Evaluation of surface condition of masonry; determining deficiencies in joints; determining differential movement in joints; determining warping, bulging or sagging of components. Visual examination includes sampling of units.	Visual examination with or without optical aids, photographic records, or other low cost tools; differential movement determined over long periods of time with use of crack movement monitoring devices.	Experience required in order to determine what to look for, what measurements to take, and what follow-up testing to specify.	Generally low cost; rapid results except for surveying method.	Trained evaluator required; primary evaluation confined to surface of structure.	4, 5, 12, 14, 32, 33, 34, 36, 39

TABLE 3.7.10. NDT Methods for Determining Properties and Physical Conditions of Masonry Units and Masonry Assemblages (*Continued*)

Test Method	Purpose of Test	Principle of Operation	User Expertise	Advantages	Limitations	References
Water penetration	Determine resistance to leakage and water penetration. Test is basically a laboratory test.	Test chamber placed against masonry with controlled temperature and humidity condition. Water is applied with increased air pressure and prime dampness observed.	Modified laboratory test. Specialized expertise required.	Provides useful information in quality of material coatings, leakage and workmanship. ASTM E514 can be adapted to in situ tests.	Expensive. Opposite side of wall may not be accessible to observe dampness.	2, 6, 8, 11, 13, 16, 17, 23, 25, 28, 30, 35

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