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ACCEPTANCE CRITERIA FOR EXPANSION ANCHORS IN STEELWORK CONNECTION AND SUSPENSION SYSTEMS

AC145

January 1999

PREFACE

Evaluation reports issued by the ICBO Evaluation Service, Inc. (ICBO ES), are based upon performance features of the *Uniform Building Code*™, ICBO *Uniform Mechanical Code*™ and related codes. Section 104.2.8 of the *Uniform Building Code* is the primary charging section upon which evaluation reports are issued. Section 104.2.8 reads as follows:

> The provisions of this code are not intended to prevent the use of any material, alternate design or method of construction not specifically prescribed by this code, provided any alternate has been approved and its use authorized by the building official.
>
> The building official may approve any such alternate, provided the building official finds that the proposed design is satisfactory and complies with the provisions of this code and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in suitability, strength, effectiveness, fire resistance, durability, safety and sanitation.
>
> The building official shall require that sufficient evidence or proof be submitted to substantiate any claims that may be made regarding its use. The details of any action granting approval of an alternate shall be recorded and entered in the files of the code enforcement agency.

The attached acceptance criteria for the general code sections noted has been issued to provide all interested parties with guidelines on implementing performance features of the codes. The attached acceptance criteria was developed and adopted following public hearings conducted by the Evaluation Committee and is effective on the date shown above. All reports issued or reissued on or after this date must comply with this criteria. If the criteria is an updated version from a previous edition, solid vertical lines (▌) in the outer margin within the criteria indicate a technical change or addition from the previous edition. Deletion indicators (➧) are provided in the outer margins where a paragraph or item has been deleted if the deletion resulted from a technical change. This criteria may be revised from time to time as the need dictates.

ICBO ES may consider alternate criteria, provided the proponent submits valid data demonstrating that the alternate criteria are at least equivalent to the attached criteria and otherwise meet the applicable performance requirements of the codes. Notwithstanding that a material, type or method of construction, or equipment, meets the attached acceptance criteria, or that it can be demonstrated that valid alternate criteria are equivalent and otherwise meet the applicable performance requirements of the codes, if the material, product, system or equipment is such that either unusual care in its installation or use must be exercised for satisfactory performance, or malfunctioning is apt to cause unreasonable property damage or personal injury or sickness relative to the benefits to be achieved by the use thereof, ICBO ES retains the right to refuse to issue or renew an evaluation report.

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1.0 INTRODUCTION

The purpose of this acceptance criteria is to establish requirements for ICBO Evaluation Service, Inc. (ICBO ES), evaluation reports on expansion anchors in structural steelwork connection or suspension systems.

2.0 DEFINITIONS

2.1 Anchor Test Series: A group of identical anchors tested under identical conditions. Identical conditions encompass anchor type, model, diameter and length; torque; spacing; edge distance; and steel strength.

2.2 Anchor Spacing (s): The measure between anchors, as a centerline-to-centerline distance.

2.2.1 Critical Spacing (s_{cr}): The minimum anchor spacing distance at which the full load-bearing capacity of an anchor is obtained without influence of neighboring anchors.

2.2.2 Minimum Spacing (s_{min}): The minimum anchor spacing distance at which the base material will not be damaged when multiple anchors are set, expanded or loaded at service loads.

2.3 Edge Distance (m): The measure between the anchor centerline and the free edge of the steel member.

2.3.1 Critical Edge Distance (m_{cr}): The minimum edge distance at which the maximum load capacity of an anchor is obtained.

2.3.2 Minimum Edge Distance (m_{min}): The minimum edge distance at which the base material will not be damaged when the anchor is set, expanded or loaded at service loads.

2.4 Expansion Anchor ("anchor"):

2.4.1 General: A mechanical fastener placed in assembled steel, designed to expand in a predrilled hole of a specified size and engage the back of the material adjacent to the hole in one or more locations, to develop shear and/or tension resistance to applied loads without any tapping or welding.

2.4.2 Type A (Torque-set) Anchor: The anchor sleeve is expanded by applying torque to a screw or bolt. Degree of anchorage is controlled by the amount of torque applied.

2.5 Steel Member Thickness (t_v): Distance through the test member that receives the test anchor.

2.6 Test Member: The steel member receiving anchors to be tested.

2.7 Testing Laboratory: A testing laboratory complying with the ICBO ES Acceptance Criteria for Laboratory Accreditation (AC89), and having the personnel, expertise, equipment and facilities for testing in accordance with this acceptance criteria.

3.0 TEST SPECIMEN

3.1 Anchors shall be of standard manufacture and representative (in such areas as dimensional specifications, materials, heat treatment, finish, etc.) of the product for which recognition is sought. Test specimen sampling shall comply with the ICBO ES Acceptance Criteria for Test Reports and Product Sampling (AC89).

3.2 Anchors shall be described as to:

3.2.1 Generic or trade name.

3.2.2 Manufacturer's catalog number.

3.2.3 Nominal thread size.

3.2.4 Nominal anchor or sleeve diameter.

3.2.5 Anchor length.

3.2.6 Permitted manufacturing tolerances.

3.2.7 Basic materials, including physical properties before and after manufacture (e.g., tensile strength, hardness and protective coatings). If the anchor consists of component parts involving different materials, differences must be noted.

3.2.8 Appropriate national standards for the materials. Reports of physical properties of materials used in test specimens must be submitted. These reports must be generated by a mill or independent testing laboratory; see Section 2.7. Where the actual material strength exceeds the specified strength, tests results must be adjusted by the ratio $\frac{F_u \text{ specified}}{F_u \text{ actual}}$ when failure is attributed to the subject anchor material. Where no physical property specifications exist, acceptable properties must be established by physical property tests.

3.2.9 Manner of field identification prior to and/or after installation. The manufacturer's name or insignia, and the type, size, and minimum steel thickness and strength must be marked on the anchor itself or on the packaging units. Every anchor, if available in more than one length, must be marked, with a manufacturer's symbol and length code, in accordance with Table 1 of this acceptance criteria.

3.2.10 Recommended installation procedures. Manufacturer's published instructions for installation, application and design must be submitted.

3.3 When anchors are recognized for exterior exposure or damp environments, evidence of durability must be established.

4.0 TESTING PROCEDURES

4.1 Anchor Installation:

4.1.1 Each diameter anchor to be recognized must be tested.

4.1.2 Holes for anchor test specimens are drilled in accordance with the manufacturer's published recommendations, including diameter and depth. Only tools typically used in field installations are permitted. Drill bits used in the test program must have bit-diameter allowable tolerances complying with Figure 1 or 2. Drill-bit dimensions and corresponding tolerances must be reported; compliance with applicable standards must be reported, when appropriate. All procedures must be conducted or directly verified by an independent testing laboratory; see Section 2.7.

4.1.3 The diameter of each drill bit must be measured before and after drilling each series of anchors (10 anchors, maximum). The drill bits must be within the diameter range described in Item 2 of Section 4.1 and Figures 1 and 2. The testing laboratory must confirm that measured diameters are within allowable tolerances.

4.1.4 All test anchors must be installed perpendicular to the surface of the test member, with a six-degree tolerance, and in a manner representative of actual field installations.

4.1.5 Installation and setting of anchors must comply with published recommendations of the manufacturer. Pertinent data (such as anchor nominal torque) must be observed and noted by the testing laboratory and/or other witnessing agency.

4.2 Proper Functioning Tests:

4.2.1 For Type A torque-set anchors, additional tests must be conducted on anchors set by using 20 percent of the minimum installation torque. The resulting ultimate ten-

sion loads must be at least 80 percent of ultimate loads at installation torque. See Table 2, Series 2, for testing schedule.

4.2.2 Maximum drill bit sizes: To verify proper functioning of anchors installed in holes that were prepared using the maximum-size drill bits that are described in Figures 1 and 2, tension tests are conducted on anchors installed in steel having the minimum strength for which recognition is sought. See Table 2, Test Series 1.

Condition of Acceptance: The average ultimate tension loads must be at least 80 percent of loads obtained on anchors tested in accordance with Table 2, Test Series 3.

4.3 Tests for Service Conditions:

4.3.1 The service conditions of anchors installed in steel are determined by testing that investigates the effects of several factors, including:

1. Anchor type.
2. Anchor materials.
3. Direction of loading.
4. Steel strength.
5. Anchor location (spacing and edge distance).
6. Thicknesses of receiving steel materials.

4.3.2 To determine service conditions, Test Series 3 through 20 shall be performed, as applicable.

4.4 Testing and Equipment:

4.4.1 Test equipment for pullout and shear loading must be adequate to impose anticipated ultimate loads and must comply with Sections 5 and 6 of ASTM E 488-90. If loading is not carried to failure, the highest value achieved will be considered the ultimate load.

4.4.2 Direction of loading for all tensile testing must be coaxial with the embedded anchor.

4.4.3 Test equipment cannot impose pullout or shear-reaction loadings on the surface or edge of the steel within a distance "*m*", as noted in Table 2 of ASTM E 488-90. Equipment used to apply shear loads must be designed to minimize frictional resistance using a surface finish specified in Section 6.4.4 of ASTM E 488-90.

4.4.4 Displacement due to shear and tension must be recorded for each test specimen. The displacement must be indicated as a function of load and direction of load application. The load-displacement curve must show no fall or plateau until 150 percent of the allowable service load is reached. See Section 5.5 of ASTM E 488-90 for measurement procedures.

4.4.5 The testing schedule must comply with Table 2. Characteristics to be evaluated include proper functioning, service conditions, spacing distance and edge distance. The following parameters will be established by the load test program, as applicable to the anchor systems:

1. Critical edge distance.
2. Minimum edge distance with appropriate load-reduction factor.
3. Critical spacing.
4. Minimum spacing with appropriate load-reduction factor.
5. Maximum and minimum steel thicknesses.

4.5 Static Tests: Static load test procedures for tension and shear must comply with this acceptance criteria and Section 8 of ASTM E 488-90.

4.6 Fire Resistance: Anchors intended for fire-resistive construction must be evaluated for load resistance during fire exposure. General guidelines for fire exposure are in UBC Standard 7-1.

5.0 TEST REPORTS AND INTERPRETATIONS

5.1 Testing laboratories shall comply with the ICBO ES Acceptance Criteria for Laboratory Accreditation (AC89).

5.2 Test reports shall comply with the ICBO ES Acceptance Criteria for Test Reports and Product Sampling (AC85). Test reports also must include information specified in Section 13 of ASTM E 488-90, and the following:

5.2.1 Mode of failure for each test (e.g., anchor pull-out, anchor shear, ductile steel failure, etc.). Where the anchor and bolt are combined in a single assembly, location of anchor-fracture failures must be noted (across major bolt diameter, across thread diameter, through unthreaded reduced-diameter portion of bolt, etc.).

5.2.2 Photographs of test equipment and typical failure.

5.2.3 Report approval by an independent professional engineer.

5.2.4 Report of anchor sampling at manufacturer's facilities, by independent testing laboratory. See Section 3.1. Report must note when high-tensile bolts, studs, or threaded rods are used in the test program and are not a standard component of the anchor. The bolt, stud, or threaded rod specifications must be noted.

5.3 An independent testing laboratory, or a qualified engineer that is not an employee of the anchor manufacturer, must verify and attest that all elements of the test program were in compliance with this acceptance criteria.

5.4 Anchors must be tested at the minimum thickness and steel strength for which recognition is desired.

5.5 Extrapolation of test data for additional anchor sizes, thicknesses or steel strengths is prohibited.

6.0 ALLOWABLE LOADS

6.1 Service Loads: Allowable tension values are determined by application of a factor of safety of five to the average ultimate tension load, with or without special inspection. Allowable shear values are determined by application of a factor of safety of five to the average ultimate shear load, with or without special inspection.

When the load test program evaluates the anchor with variations in spacing, edge distance or steel thickness, allowable loads may need to be adjusted accordingly. Test load results can be analyzed by comparing loads to develop appropriate load adjustment factors, which are then applied to the optimum allowable anchor load.

When more than one load adjustment factor must be applied (such as in the case of anchors installed at reduced spacings and reduced edge distances), the product of the factors is used to determine design loads.

6.2 Combined Loads: The allowable load for anchors subjected to combined shear and tension forces can be determined by the following equation:

$$(P_s/P_t)^{5/3} + (V_s/V_t)^{5/3} \leq 1$$

where:

P_s = Applied service tension load.
P_t = Service tension load.
V_s = Applied service shear load.
V_t = Service shear load.

6.3 Displacement: Anchor displacement under allowable load shall be reported.

6.4 Limitations:

6.4.1 Each evaluation report shall note that use of anchors in resisting earthquake loads is beyond the scope of that report.

6.4.2 Evaluation reports shall note that anchors shall not be subjected to vibratory loads. Sources of vibratory loads

include reciprocating engines, crane loads and moving loads from vehicles.

6.4.3 Each evaluation report shall note that, in forming connection joints, use of standard fasteners in combination with other fasteners, such as welds or rivets, is beyond the scope of that report.

7.0 QUALITY CONTROL AND QUALITY ASSURANCE

The manufacture of anchors must be under a quality control and quality assurance program with periodic inspections by either a quality control agency accredited by ICBO ES or a compliance assurance/inspection agency recognized by the National Evaluation Service, Inc. (NES). The program must be documented in a manual, jointly developed by the manufacturer and the agency, complying with the ICBO ES Acceptance Criteria for Quality Control Manuals (AC10). Criteria for acceptance may be derived from test results of anchor test series or recognized specifications. Each manufacturer recognized under this acceptance criteria in an ICBO ES evaluation report shall maintain an in-house quality control program. The in-house program shall be documented in the quality control manual and shall require the manufacturer to conduct the following quality control evaluations:

7.1 Dimensions of all components.

7.2 Functioning of threads and assembly.

7.3 Protective coating thickness.

7.4 Mechanical properties (e.g., elastic limit, tensile strength of materials). Direct confirmation or supplier test results are needed.

7.5 Hardness of cold-formed, quenched, hardened or machined components. Direct confirmation or supplier test results are needed.

7.6 Identification markings.

The in-house quality control evaluations are conducted on three randomly selected anchors from each diameter, either from lots of 10,000 bolts, or, for smaller production runs, at weekly intervals. The quality assurance agency shall arrange for evaluating the anchors in a similar manner during its inspections or shall, using the sampling procedure herein, sample anchors for evaluation after the inspection.

TABLE 1—LENGTH IDENTIFICATION CODES

CODE		LENGTH OF ANCHOR (inches)	LENGTH OF ANCHOR (mm)
A	Black	$1^1/_2 < 2$	38 < 51
B	White	$2 < 2^1/_2$	51 < 63
C	Red	$2^1/_2 < 3$	63 < 76
D	Green	$3 < 3^1/_2$	76 < 89
E	Yellow	$3^1/_2 < 4$	89 < 102
F	Blue	$4 < 4^1/_2$	102 < 114
G	Purple	$4^1/_2 < 5$	114 < 127
H	Brown	$5 < 5^1/_2$	127 < 140
I	Orange	$5^1/_2 < 6$	140 < 152
J	N/A	$6 < 6^1/_2$	152 < 165
K	N/A	$6^1/_2 < 7$	165 < 178
L	N/A	$7 < 7^1/_2$	178 < 191
M	N/A	$7^1/_2 < 8$	191 < 203

CODE	LENGTH OF ANCHOR (inches)	LENGTH OF ANCHOR (mm)
N	$8 < 8^1/_2$	203 < 216
O	$8^1/_2 < 9$	216 < 229
P	$9 < 9^1/_2$	229 < 241
Q	$9^1/_2 < 10$	241 < 254
R	10 < 11	254 < 267
S	11 < 12	267 < 305
T	12 < 13	305 < 330
U	13 < 14	330 < 366
V	14 < 15	366 < 381
W	15 < 16	381 < 406
X	16 < 17	406 < 432
Y	17 < 18	432 < 457
Z	18 < 19	457 < 483

TABLE 2—TESTING SCHEDULE

TEST SERIES NUMBER	TEST	ASTM E 488 SECTION	ICBO ES ACCEPTANCE CRITERIA (AC145) SECTION	STEEL TENSILE STRENGTH[1]	NUMBER OF TESTS				DRILL SIZE[2]	REMARKS[4]
					All Diameters	Small	Medium	Large		
	PROPER FUNCTIONING									
1	Tolerance on drill holes	—	4.2.1	Min.	—	5	5	5	Max.	—
2	Intensity of expansion	—	4.2.1	Min.	—	5	5	5	Med.	Torque = 20% of normal
	SERVICE CONDITIONS (Direction of loading: axial tension)									
3	Single anchors	8.4.1	—	Min.	5	—	—	—	Med.	—
4	Single anchors	8.4.1	—	Med.	5	—	—	—	Med.	—
5	Single anchors	8.4.1	—	Max.	5	—	—	—	Med.	—
6	Single anchors, critical edge distance	—	4.4.5	Min.	—	5	5	5	Med.	$m = m_{cr}$
7	Single anchors, minimum edge distance	—	4.4.5	Min.	—	5	5	5	Med.	$m = m_{min}$
8	Single anchors, critical edge distance	—	4.4.5	Max.	—	5	5	5	Med.	$m = m_{cr}$
9	Single anchors, minimum edge distance	—	4.4.5	Max.	—	5	5	5	Med.	$m = m_{min}$
10	Group of 4 anchors, critical edge distance	—	—	Min.	—	5	5	5	Med.	$s = s_{cr}$; $m = m_{cr}$
11	Group of 4 anchors, minimum spacing distance	—	—	Min.	—	5	5	5	Med.	$s = s_{min}$; $m = m_{cr}$

(continued)

TABLE 2—TESTING SCHEDULE—(Continued)

TEST SERIES NUMBER	TEST	ASTM E 488 SECTION	ICBO ES ACCEPTANCE CRITERIA (AC145) SECTION	CONCRETE COMPRESSIVE STRENGTH[1]	NUMBER OF TESTS				DRILL SIZE[2]	REMARKS[4]
					All Diameters	Small	Medium	Large		
	SERVICE CONDITIONS (Direction of loading: shear)									
12	Single anchors[3]	8.4.2	—	Min.	5	—	—	—	Med.	ASTM E 488; m
13	Single anchors, critical edge distance	—	4.4.5	Min.	—	5	5	5	Med.	$m = m_{cr}$
14	Single anchors, minimum edge distance	—	4.4.5	Min.	—	5	5	5	Med.	$m = m_{min}$
15	Single anchors, critical edge distance	—	4.4.5	Max.	—	5	5	5	Med.	$m = m_{cr}$
16	Single anchors, minimum edge distance	—	4.4.5	Max.	—	5	5	5	Med.	$m = m_{min}$
17	Group of 2 anchors	—	—	Min.	—	—	5	—	Med.	$m = m_{cr}$.; $s = s_{cr}$
18	Group of 2 anchors	—	—	Min.	—	—	5	—	Med.	$m = m_{cr}$; $s = s_{min}$
	SERVICE CONDITIONS (Direction of loading: oblique tension 45°)									
19	Single anchors	—	—	Min.	3	—	—	—	Med.	$m = m_{cr}$
20	Single anchors	—	—	Max.	3	—	—	—	Med.	$m = m_{cr}$

[1]Where anchors are evaluated at more than one steel strength level, certain tests must be repeated at each steel strength.

[2]See Figures 1 and 2 for range of drill bit sizes.

[3]Tests for "single anchors, critical edge distance (max.)" (No. 13 series) should be tested first. If steel failure occurs, then tests for single anchors (No. 12 series) can be deleted.

[4]s = spacing, m = edge distance.

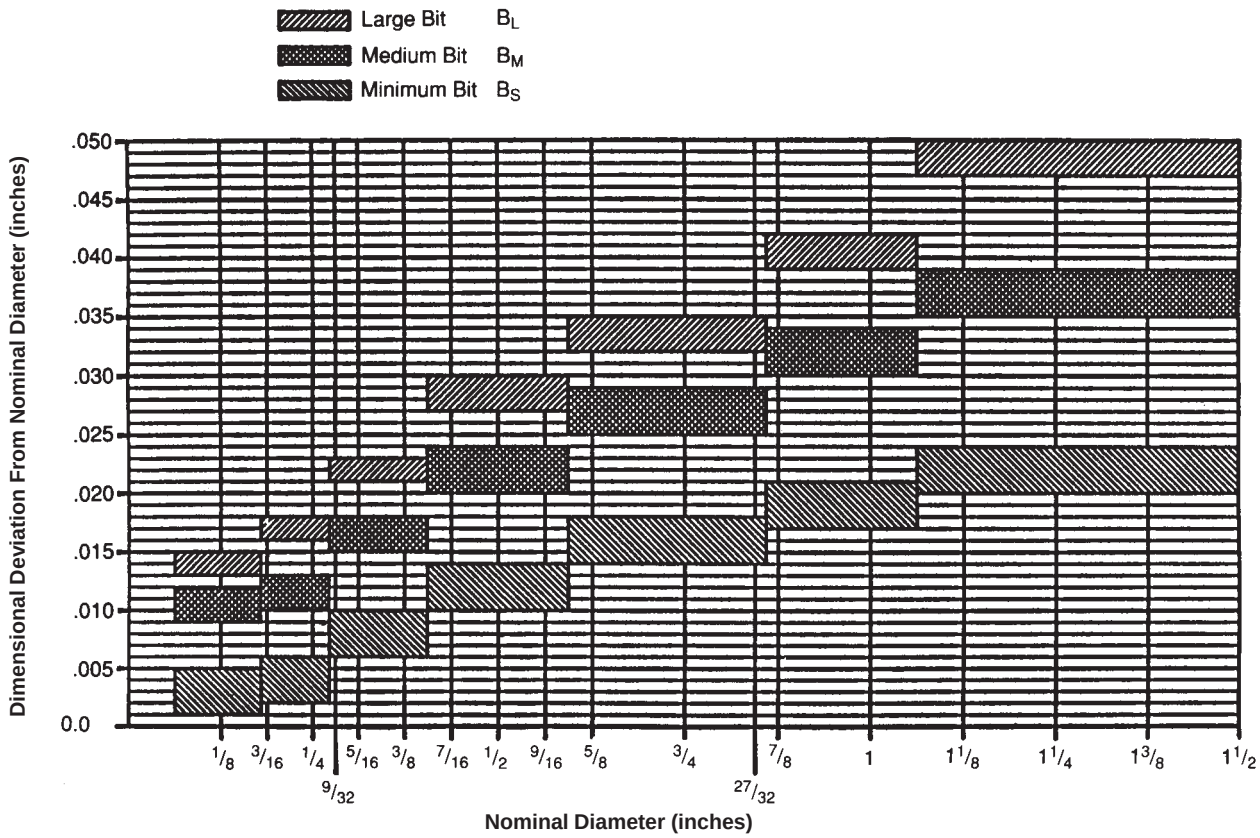

FIGURE 1—CARBIDE-TIPPED DRILL BIT TEST DIAMETER TOLERANCES

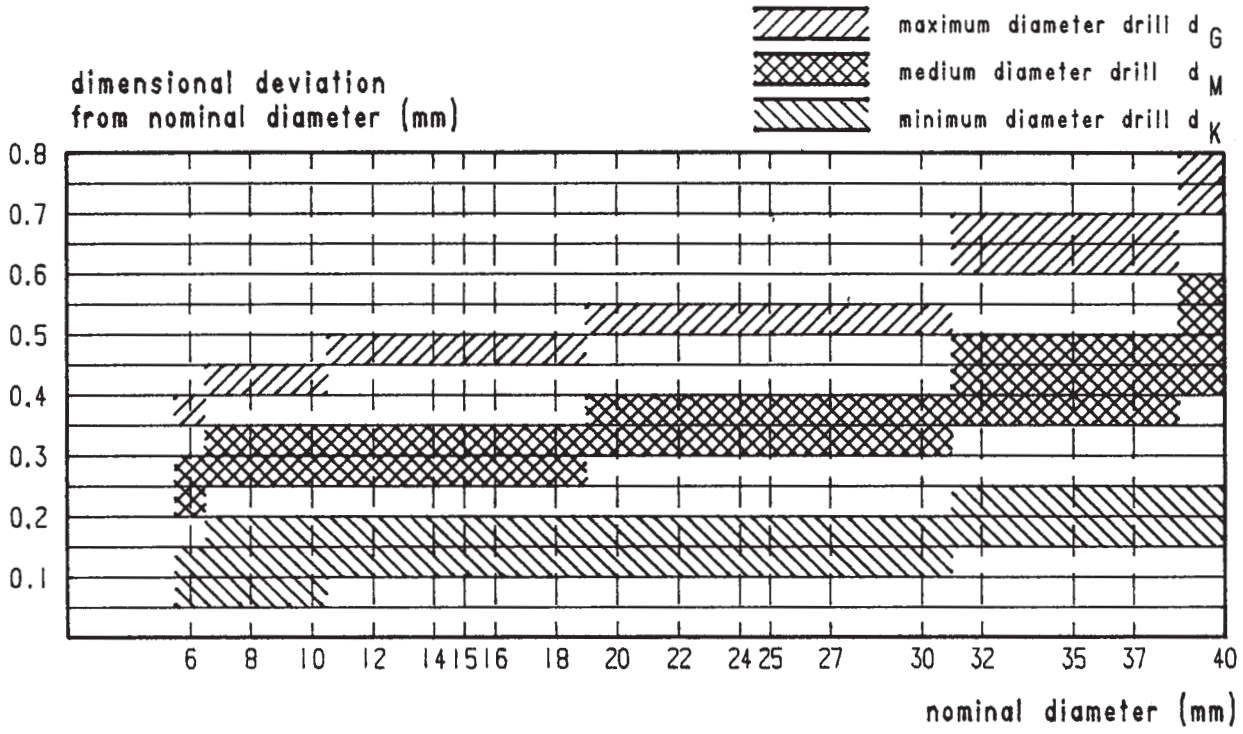

FIGURE 2—CUTTING DIAMETER OF CARBIDE-TIPPED METRIC HAMMER DRILL BITS