U.S. NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REGULATORY RESEARCH

July 2002
Division 1
Draft DG-1099

DRAFT REGULATORY GUIDE

Contact: H.L. Graves (301)415-5880

DRAFT REGULATORY GUIDE DG-1099

ANCHORING COMPONENTS AND STRUCTURAL SUPPORTS IN CONCRETE

A. INTRODUCTION

This draft regulatory guide is being issued to provide guidance to licensees and applicants on methods acceptable to the NRC staff for complying with the NRC's regulations in the design, evaluation, and quality assurance of anchors (steel embedments) used for component and structural supports on concrete structures.

General Design Criterion (GDC) 1, "Quality Standards and Records," of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," requires, in part, that structures, systems, and components (SSCs) important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. In addition, GDC 2, "Design Bases for Protection Against Natural Phenomena," and GDC 4, "Environmental and Dynamic Effects Design Bases," require, in part, that such SSCs be designed to withstand the effects of natural phenomena and to accommodate the effects of and be compatible with the environmental conditions associated with normal operation and postulated accidents. Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50 establishes overall quality assurance for SSCs important to safety. Appendix S, "Earthquake Engineering Criteria For Nuclear Power Plants," to 10 CFR Part 50, states, in part, requirements for the implementation of GDC 2 with respect to earthquakes.[1]

Licensees and applicants may propose means other than those specified by the provisions of the Regulatory Position of this guide for meeting applicable regulations. No new

[1] Appendix S to 10 CFR Part 50 applies to applicants for a design certification or combined license pursuant to 10 CFR Part 52 or a construction permit or operating license pursuant to 10 CFR Part 50 on or after January 10, 1997. However, for either an operating license applicant or holder whose construction permit was issued before January 10, 1997, the earthquake engineering criteria in Section VI of Appendix A to 10 CFR Part 100 continue to apply.

standards are being imposed by this regulatory guide. Implementation of this guidance by licensees will be on a strictly voluntary basis.

Regulatory guides are issued to describe to the public methods acceptable to the NRC staff for implementing specific parts of the NRC's regulations, to explain techniques used by the staff in evaluating specific problems or postulated accidents, and to provide guidance to applicants. Regulatory guides are not substitutes for regulations, and compliance with regulatory guides is not required. Regulatory guides are issued in draft form for public comment to involve the public in developing regulatory positions. Draft regulatory guides have not received complete staff review or approval; they therefore do not represent official NRC staff positions.

The information collections contained in this draft regulatory guide are covered by the requirements of 10 CFR Part 50, which were approved by the Office of Management and Budget (OMB), approval number 3150-3011. The NRC may not conduct or sponsor, and a person is not required to respond to, a request for information or an information collection requirement unless the requesting document displays a currently valid OMB control number.

B. DISCUSSION

Component and structural supports are fastened to the concrete building structure by anchors (steel embedments) that transmit forces to the concrete building structure by bearing, shear, tension, or a combination thereof. Structural failure of piping supports for safety systems and questions concerning the performance of one type of steel embedment, the expansion anchor bolt, led to the issuance of Inspection and Enforcement Bulletin (IEB) 79-02, "Pipe Support Base Plate Designs Using Concrete Expansion Anchor Bolts," in March of 1979. Review of reports required by IEB 79-02 revealed that industry practices varied. No consistency existed in the design and installation of such anchors as grouted anchors, embedded plates, or inserts. Utilities and anchor manufacturers were prompted by these inconsistencies to conduct research to answer questions raised by IEB 79-02. In October 1980, the American Concrete Institute released Appendix B, “Steel Embedments,“ to ACI 349-80, “Code Requirements for Nuclear Safety Related Concrete Structures.” The design methodology and code standards in Appendix B to ACI 349-80 were based on a limited amount of available test data.

In December 1980, the NRC designated "Seismic Qualification of Equipment in Operating Plants" as Unresolved Safety Issue (USI) A-46. The objective of USI A-46 was to develop alternative seismic qualification methods and acceptance criteria that could be used to assess the capability of mechanical and electrical equipment in operating nuclear power plants to perform their intended safety functions. Since equipment is usually anchored to the concrete structure through steel embedments, it was necessary to ensure that the embedments were capable of resisting seismic loads.

In March 1988, in accordance with the provisions of 10 CFR Part 21, it was reported that tests of some expansion anchor bolts had disclosed that the previously recommended minimum edge distance from an unsupported edge of five times the anchor bolt diameter might be insufficient to develop 100% of the recommended anchor capacity. The issue of minimum edge distance was incorporated into USI A-46.

The Seismic Qualification Utility Group (SQUG) developed a Generic Implementation Plan (GIP), including criteria and walkdown procedures, that was used to resolve the concerns of USI A-46. Following NRC approval of the GIP, each utility conducted a walkdown of its nuclear facilities using the GIP criteria and procedures.

The criteria and procedures specified for anchorage walkdown in the GIP contained specific information related to bolt strength. The GIP, including criteria and walkdown procedures, has been reviewed and accepted by the NRC.

Since the release of Appendix B to ACI 349-80 in 1980 and the resolution of USI A-46, extensive work has been done by ACI 349 code committee and others in the industry (EPRI NP-5228). Recent testing sponsored by industry groups in the United States and Europe and by the NRC has increased the amount and type of test data available to code committees (ASCE, NUREG/CR-5434, NUREG/CR-2999, NUREG/CR-5563, and SP-130).

As a result of extensive studies and tests performed since the late 1980s, questions were raised regarding the design methodology used in Appendix B to ACI 349-80. These questions were on the shape of the anchor pullout cone under tensile loads, behavior of bolt groups, and edge conditions. Traditionally, the pullout cone has been assumed to be a 45° cone initiating at the bearing edge of the anchor (anchor head) and radiating toward the free surface of the concrete member. However, later research and test results have shown the pullout cone to be closer to a 35° cone and has also shown that the concrete breakout failures for anchor bolt groups and edge conditions were different. Based on these latest findings, a new methodology, the Concrete Capacity or "CC-Method," was proposed to the ACI 349 code committee by independent researchers (Fuchs, Eligehausen, and Breen). After an extensive review of all available test data, in February 2001 the ACI 349 code committee issued a revision to Appendix B that was based, in part, on the CC-Method.

Anchors used in nuclear power plants may need to withstand stress for long periods of time and may need to compensate for additional transient-imposed stresses as a result of environmental effects. Thus, it is necessary to carefully evaluate anchor performance, taking into consideration the environment to which the anchors are subjected (ACI 355). This Draft Regulatory Guide DG-1099 generally endorses Appendix B (February 2001) to ACI 349-01, with exceptions in the area of load combinations. In addition, the guide has supplementary recommendations in the areas of materials, installation, inservice inspection, and the use of anchors in masonry walls.

Discussion of Regulatory Positions

This regulatory guide sets forth Regulatory Positions on the New Appendix B to ACI 349-01. The reasons for each of these regulatory positions are as follows.

Regulatory Position 1 endorses Appendix B to ACI 349-01. The notations and definitions in Sections B.0, “Notation,” and B.1, “Definitions,” are acceptable to the NRC staff because they reflect the latest industry practices. However, clarification is needed in Section B.2.2 as to what type of grouted embedments are excluded from the code.

Regulatory Position 1.2 supplements Section B.3, “General Requirements,” of Appendix B in three areas: load combinations, testing, and materials. It is recommended that load combinations outlined in Section 9.2 of ACI 349-01 and specified in Section B.3.2 of Appendix B be changed as discussed in Regulatory Position 1.3. Section B.3.3 requires testing post-installed anchors in cracked concrete under seismic loads. The NRC staff agrees with the requirement of Section B.3.3, but also recommends that ASTM E488-96, “Standard Test Methods for Strength of Anchors in Concrete and Masonry Elements,” be used as a guide for establishing a test program because ASTM E488-96 is a recent standard based on industry consensus. ACI Code Committee 355, Anchorage to Concrete, developed a document on a test method for evaluating the performance of post-installed mechanical anchors in concrete, which was published in ACI 355.2-01, effective January 2002.

Section B.3.7 states that material standards should be specified by the Engineer so that embedment design is compatible with the attachment. In general, specifications require that metal anchors be made of a material that is resistant to corrosive conditions or coated with a protective material. In the case of metal anchors, the material must be stable in the concrete of the support structure and not cause any chemical reactions that could adversely affect the concrete or any reinforcement that may be present.

Regulatory Position 1.3 endorses Section B.4, “General Requirements for Strength of Structural Anchors,” of ACI 349-01. However, the staff disagrees with Section B.4.4, which provides that the load combinations of Section 9.2 of ACI 349-01 should be used. The staff agrees with the strength reduction factors given in Section B.4.4, but recommends that load factors consistent with SRP Section 3.8.4, “Other Seismic Category I Structures,” be applied to the load combinations given in Section 9.2 of ACI 349-01.

Regulatory Position 1.4 endorses Section B.5, “Design Requirements for Tensile Loading,” and Section B.6, “Design Requirements for Shear Loading,” of Appendix B. The NRC staff endorses Sections B.5 and B.6 because they are based on extensive test data and incorporate the latest knowledge on the subject.

Regulatory Position 1.5 endorses Section B.7, “Interaction of Tensile and Shear Forces,” and B.8, “Required Edge Distances, Spacings, and Thicknesses to Preclude Splitting Failure,” of Appendix B. The NRC staff endorses Sections B.7 and B.8 because they are based on test data and incorporate the latest knowledge on the subject.

Regulatory Position 1.6 endorses and supplements Section B.9, “Installation of Anchors.” Tests have shown that the proper installation of anchors is of prime importance in ensuring good anchor performance. The intentions of the guide are not to specify a detailed program for anchor installation but to ensure that the factors important for good anchor performance are considered before the anchor is installed. In addition, it is necessary to provide a sufficient preload to expansion anchors to set the anchor mechanism, limit the initial slip of the anchor, and aid in withstanding cyclic loads.

Regulatory Position 1.7 endorses Section B.10, “Structural Plates, Shapes, and Specialty Inserts,” and Section B.11, “Shear Capacity of Embedded Plates and Shear Lugs,” because they are based on test data and incorporate the latest knowledge on the subject. For Section B.12, “Grouted Embedments,” the NRC staff recommends that code requirements be followed.

Section B.9 of Appendix B states that the Engineer should specify an anchor inspection program. Therefore, Regulatory Position 2 recommends the creation of guidelines to help ensure that anchors are properly installed and provide satisfactory service throughout the life of the structure. An anchor inspection program is to cover the installation and inservice conditions of anchors. An inspection of anchors during the installation stage will verify that they are of the specified size and type and that thread stripping has not occurred. Items recommended for inspection during and after the installation stage include the items discussed in Regulatory Positions 1.6 and 2 of this guide.

Appendix B to ACI 349-01 does not include masonry in its scope; therefore Regulatory Position 7 offers guidance on the use of anchors in masonry. The extensive use of anchors (expansion and others) has led to considerable concern over the behavior of anchors in concrete masonry. Manufacturers generally indicate only the load capacities for anchors tested in cast-in-place concrete and do not recommend expansion anchors for use in concrete masonry. Until recently, the use of anchors in masonry was not subject to licensing review. Even though most standards and architect/engineer’s specifications prohibit the use of anchors in concrete masonry units (CMUs), a review of licensees’ responses to IEB 79-02 indicated the use of anchors in CMUs.

Licensees’ use of anchors in CMUs was limited in most cases to a small number of piping supports for Seismic Category I piping in a few plants, which raised questions about the anchors' performance and capabilities in concrete block walls. The limited amount of data available on static tests performed on anchor bolts installed in concrete block walls indicates that the ultimate capacity of bolts in concrete block walls is lower than that of the same type and size anchors in cast-in-place concrete. It is also expected that, under dynamic loading, the ultimate capacity of anchors will be further reduced. Until standards address anchoring in masonry are developed, the use of anchors in block walls is not recommended.

C. REGULATORY POSITION

The following Regulatory Positions describe minimum recommendations to qualify, design, install, and inspect steel embedments installed in concrete to support components and structures.

1. The procedures and standards of Appendix B to ACI 349-01 are acceptable to the NRC staff as described and supplemented below. The recommendations are applicable to the types of anchors discussed in Section B.1, "Definitions," and B.2, “Scope,” of Appendix B to ACI 349-01.

1.1 The notations and definitions given in Sections B.0 and B.1 of Appendix B to ACI 349-01 are acceptable to the NRC staff. The position on grouted anchors is in Regulatory Position 1.7.

1.2 The position on load combinations is given in Regulatory Position 1.3. In addition to the guidance of Section B.3.3 of Appendix B, the testing recommendations defined in ASTM E488-96, “Strength of Anchors in Concrete and Masonry Elements,” are acceptable to the NRC staff as a guide for establishing a testing program. Test methods not covered by ASTM E488-96 (e.g., combined tension and shear, cracked concrete) should be established and executed using good engineering judgment. ACI 355.2-01, “Evaluating the Performance of Post-Installed Anchors in Concrete,” provides guidance acceptable to the NRC staff for determining whether post-installed mechanical anchors are acceptable for use in uncracked as well as cracked concrete. For materials consideration, the NRC staff recommends, as a minimum, that anchors be designed, manufactured, and tested to be compatible with the load application, environment, and installation conditions.

1.3 The load factors used in Section 9.2.1 of ACI 349-01 are acceptable to the NRC staff except for the following:

1.3.1. In load combinations 9, 10, and 11, $1.2T_o$ should be used in place of $I.05T_o$.

1.3.2. In load combination 6, $1.5P_a$ should be used in place of $1.25P_a$.

1.3.3. In load combination 7, $1.25P_a$ should be used in place of $1.15P_a$.

1.4 The design standards given in Sections B.5, ”Design Requirements for Tensile Loading,” and B.6, “Design Requirements for Shear Forces,” are acceptable to the staff.

1.5 The design standards given in Sections B.7, “Interaction of Tensile and Shear Forces,” and B. 8, “Required Edge Distances, Spacing, and Thickness To Preclude Failure,” are acceptable to the staff.

1.6 Checks to be considered in the installation of expansion anchor bolts are:

- Correct hole diameter
- Proper embedment depth
- Drill hole angularity is within established limits
- Edge distance and spacing of anchors are to specified values
- Anchor is threaded properly
- Plate thickness meets specified size and thickness values
- Plate bolt-hole size is within established limits
- Anchor has been correctly preloaded
- Correct bolt diameter and length are used
- Bolt hole has been cleared of drill dust
- Concrete is sound (free of voids)
- Grout has been mixed and installed to specifications.

1.7 The design standards given in Sections B.10, “Structural Plates, Shapes, and Specialty Inserts,” and B.11, “Shear Capacity of Embedded Plates and Shear Lugs,” are acceptable to the NRC staff. When grouting is the only option, it is recommended that tests be performed in accordance with Sections B.12.3 and B.12.4 of Appendix B.

2. All anchors should be inspected to verify that they are of the specified size and type. Installation standards should be consistent with accepted industry-specified tolerances. Anchor systems that are external to the concrete surface should be inspected regularly during the life of the structure. In addition to the requirements in Section B.9.2 of Appendix B, the NRC staff recommends the following minimum post-installed 6-step inspection program to verify the proper installation of post-installed anchors.

1. **Are the nut and anchor bolt tight?** This step will detect certain types of installation defects: oversized holes, total lack of preload, loose nuts, damaged subsurface concrete, and missing plug (for shell type). To implement this step, it is necessary to place a wrench on the bolt head or nut and to apply a torque. A well-installed bolt should not rotate under the torque applied equal to about 20% of the normal installation torque.

2. **Are there washers between the equipment base and the anchor bolt nut or bolt head?** Washers are required for all bolts. Oversize washers are recommended for thin equipment bases. Lock washers are recommended where even low-level vibration exists.

3. **Is the bolt spacing in accordance with the anchorage design?**

4. **Is the distance between the bolt and any free concrete surface in accordance with the anchorage design?**

5. **Is the concrete sound and uncracked?** This inspection element will detect gross defects in the concrete that could affect the holding power of expansion anchor bolts. Hairline shrinkage cracks in the vicinity of an expansion bolt are not a matter of concern so long as the design strength is based upon cracked concrete. If cracks in the vicinity exceed about 0.01 inch (0.3mm), the design strength should be appropriately reduced.

6. **Is there a significant gap between the equipment base and the concrete surface?** This inspection element will identify situations where the equipment base is raised. This detail causes concern because shear forces result in flexural stresses in the anchor bolt. A gap of less than about 1/4 inch is not significant and should be ignored. Anchorages with gaps larger than about 1/4 inch should be evaluated in more detail.

For maximum assurance of adequacy, all six of these steps should be performed for all bolts. However, adequate assurance can be achieved by a less extensive inspection program. Inspection steps 2 through 6, which are simple and mainly visual, should be applied to each bolt. However, a sampling approach might be used for the tightness check in step 1. A sampling program for expansion anchor bolts used in pipe support base plates was recommended in Appendix A of NRC IE Bulletin 79-02. The essential features of this program may be adopted for equipment anchorage as shown in Appendix A of this draft guide.

3. All quality assurance standards of ASME NQA-2,1983, "Quality Assurance Program Requirements for Nuclear Facilities," are applicable to load-bearing steel embedments and other load-bearing components of component and structural supports.

4. The concrete constituents and embedded materials should be compatible with the anticipated environmental conditions to which they will be subjected during the life of the plant.

5. Loads and forces on embedments should be properly evaluated to account for baseplate flexibility and eccentricity of connections and the dynamic (strain rate and low-cycle fatigue) effects of loads and forces.

6. The hardness, materials, and heat treatment of high-strength anchor bolts and studs ($F_y > 110$ ksi) should be carefully controlled to prevent environmental and stress-corrosion cracking.

7. Because anchors are not generally specified for masonry, the NRC staff does not recommend the use of any type of anchor discussed in this guide to attach Seismic Category I components or systems to concrete block walls that are seismically qualified, except for extremely low load applications. In locations where it is impossible to avoid the use of anchors, the staff recommends bolting through the block wall.

D. IMPLEMENTATION

The purpose of this section is to provide information to licensees and applicants regarding the NRC staff's plans for using this regulatory guide.

This proposed revision has been released to encourage public participation in its development. Except in those cases in which the applicant or licensee proposes an acceptable alternative method for complying with specified portions of the NRC's regulations, the method to be described in the active guide reflecting public comments will be used in the evaluation of anchors (steel embedments) used for component and structural supports on concrete structures.

REFERENCES

ACI 349-01 and 349R-01, "Code Requirements for Nuclear Safety Related Concrete Structures," with Appendix B, "Steel Embedments," (ACI 349-01) and Commentary (ACI 349R-01) American Concrete Institute, Farmington Hills, Michigan, 2001. **Appendix B,** "Anchoring to Concrete," to ACI 349-01, "Code Requirements for Nuclear Safety Related Concrete Structures."

ACI 349-97, "Code Requirements for Nuclear Safety Related Concrete Structures," with Appendix B, "Steel Embedments," American Concrete Institute Detroit, Michigan, 1997.

ACI 349-80, "Code Requirements for Nuclear Safety Related Concrete Structures," with Appendix B, "Steel Embedments," American Concrete Institute, Detroit, Michigan, 1980.

ACI 355.2-01/ACI 355.2R-01, "Evaluating the Performance of Post-Installed Mechanical Anchors in Concrete" (ACI 355.2-01) and "Commentary" (ACI 355.2R-01), American Concrete Institute, Farmington Hills, MI, 2001.

ASCE Task Group on Steel Embedments, "State-of-the-Art Report on Steel Embedments," Vol. 2, p. 1080, in *Proceedings of the Conference: Structural Engineering in Nuclear Facilities*, Raleigh, North Carolina, American Society of Civil Engineers, September 1984.

ASTM E 488-96, "Standard Test Methods for Strength of Anchors in Concrete and Masonry Elements," American Society for Testing and Materials, West Conshohocken, PA, 1996.

EPRI NP-5228, "Seismic Verification of Nuclear Plant Equipment Anchorage," Volumes 1 and 2, May 1987.

Fuchs, W., R. Eligehausen, and J.E. Breen, "Concrete Capacity Design (CCD) Approach for Fastening to Concrete," *ACI Structural Journal*, Volume 92, No. 1, January-February 1995.

GIP, Memo from J.G. Partlow, USNRC, to All USI A-46 Plant Licensees Who Are Members of the Seismic Qualification Utility Group (SQUG), May 22, 1992. (NUDOCS Accession Number 9205190366)[1]

IEB 79-02, "Pipe Support Base Plate Designs Using Concrete Expansion Anchor Bolts," Inspection and Enforcement Bulletin, USNRC, Revision 2, November 1979. (NUDOCS Accession Number 7908220136)[1]

NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," Section 3.8.4, "Other Seismic Category I Structures," Revision 1, USNRC, 1981.[1]

[1] Copies are available for inspection or copying for a fee from the NRC Public Document Room at 11555 Rockville Pike (first floor), Rockville, MD; the PDR's mailing address is USNRC PDR, Washington, DC 20555; telephone (301)415-4737 or 1-(800)397-4209; fax (301)415-3548; e-mail <PDR@NRC.GOV>.

NUREG/CR-2999, M.R. Lindquist, "Final Report on USNRC Anchor Bolt Study Data Survey and Dynamic Testing," USNRC (HEDL-MISC-7246), December 1982. [2]

NUREG/CR-5434, R. Klingner et al., "Anchor Bolt Behavior and Strength During Earthquakes," USNRC, August 1998.

NUREG/CR-5563, R. Klingner et al., "A Technical Basis for Revision to Anchorage Criteria," USNRC, March 1999.

SP-130, "Anchors in Concrete: Design and Behavior," G.A. Senkiw and H.B. Lancelot, Editors, SP-103, American Concrete Institute, Farmington Hills, MI, 1991.

[2] Copies are available at current rates from the U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20402-9328 (telephone (202)512-1800); or from the National Technical Information Service by writing NTIS at 5285 Port Royal Road, Springfield, VA 22161; (telephone (703)487-4650; <http://www.ntis.gov/ordernow>. Copies are available for inspection or copying for a fee from the NRC Public Document Room at 11555 Rockville Pike, Rockville, MD; the PDR's mailing address is USNRC PDR, Washington, DC 20555; telephone (301)415-4737 or (800)397-4209; fax (301)415-3548; email is PDR@NRC.GOV.

APPENDIX A
Sampling Program for Anchor Bolts

This sampling program for expansion anchor bolts used in pipe support base plates was recommended in Appendix A of NRC IE Bulletin 79-02. The essential features of this program may be adopted for equipment anchorage.

Perform inspection step 1 in Regulatory Position 2 on at least 25% of the bolts in every equipment anchorage. If the selected bolts do not pass the inspection, perform step 1 on all bolts in the anchorage. OR

Perform inspection step 1 on a randomly selected statistical sample of bolts. The size of the sample and the number of nonconformances should be such that there is a 95% confidence of no more than 5% nonconforming bolts. This can be determined as follows:

$$R' = R + Z\left(\frac{R(1-R)}{n}\right)^{1/2} \frac{N - n}{N - 1}^{1/2}$$

where:

R' = Upper limit of the true defect rate at a specified confidence level (R' = 0.05 in this application)
R = Defect rate observed in sample
Z = Confidence coefficient for a normally distributed statistical model of test data. For a 95% confidence level, Z= 1.65.
n = Test sample size
N = Total population from which test sample was selected

Table 1 gives the allowable number of nonconforming bolts as a function of the population size N and the test sample size n.[1]

When the failure rate for this check exceeds the limitations corresponding to 95% confidence of no more than 5% nonconforming bolts, the installation procedure should be considered to be unacceptable.

[1]Adapted from: EPRI-NP-5228, May 1987.

Table 1
ALLOWABLE NUMBER OF NONCONFORMING ANCHORS

Allowable Number of Nonconforming Anchors for Test Sample Size, n												
Total Population Size, N	40	60	80	100	150	200	250	300	350	400	450	500
100	1	2	3	5	---	---	---	---	---	---	---	---
200	1	1	2	3	6	10	---	---	---	---	---	---
300	1	1	2	3	5	7	10	15	---	---	---	---
400	1	1	2	3	5	7	9	12	15	20	---	---
500	1	1	2	3	5	7	9	12	14	17	20	25
600	1	1	2	3	5	7	9	11	14	16	19	22
700	1	1	2	3	4	7	9	11	13	16	18	21
800	1	1	2	3	4	6	9	11	13	16	18	21
900	1	1	2	3	4	6	8	11	13	15	18	20
1,000	1	1	2	3	4	6	8	11	13	15	17	20

REGULATORY ANALYSIS

1. STATEMENT OF THE PROBLEM

Structural failure of piping supports for safety systems and questions concerning the performance of expansion anchors led to the issuance of Inspection and Enforcement Bulletin (IEB) 79-02, "Pipe Support Base Plate Designs Using Concrete Expansion Anchor Bolts," in March of 1979. Review of reports required by IEB 79-02 revealed that industry practices varied. No consistency existed in the design and installation of such anchors as grouted anchors, embedded plates or inserts. Utilities and anchor manufacturers were prompted by these inconsistencies to conduct research to answer questions raised by IEB 79-02. Industry codes and standards writing groups began to address the anchorage issue in seminars and reports. In October 1980, the American Concrete Institute released Appendix B, “Steel Embedments,“ to ACI 349-80, “Code Requirements for Nuclear Safety Related Concrete Structures.” Appendix B design methodology and code standards was based on a limited amount of available test data.

In December 1980, the NRC designated "Seismic Qualification of Equipment in Operating Plants" as Unresolved Safety Issue (USI) A-46. The objective of USI A-46 was to develop alternative seismic qualification methods and acceptance criteria that could be used to assess the capability of mechanical and electrical equipment in operating nuclear power plants to perform their intended safety functions. Since equipment is usually anchored to the concrete structure through anchor bolts, it was necessary to ensure that the bolts were capable of resisting seismic loads.

The Seismic Qualification Utility Group (SQUG) developed a Generic Implementation Plan (GIP), including criteria and walkdown procedures that were used to resolve the concerns of USI A-46. Following NRC approval of the GIP, each utility conducted a walkdown of its nuclear facilities using the GIP criteria and procedures.

The criteria and procedures specified for anchorage walkdown in the GIP contained specific information related to bolt strength under dynamic conditions. The GIP, including criteria and walkdown procedures, has been reviewed and accepted by the NRC.

Since the release of Appendix B to ACI 349-80 and the resolution of USI A-46, extensive work has been done by ACI code committee 349 and others in the industry. Recent testing sponsored by industry groups in the United States and Europe and by the NRC has increased the amount and type of test data available to code committees.

As a result of extensive studies and tests performed since the late 1980s, questions were raised regarding the design methodology (shape of the anchor pullout cone under tensile loads) used in Appendix B to ACI 349-80. Traditionally the pullout cone has been assumed to be a 45° cone initiating at the bearing edge of the anchor (anchor head) and radiating toward the free surface of the concrete member. However, later research and test results have shown the cone to be closer to a 35° cone. Based on these latest findings, a new methodology, the Concrete Capacity, or "CC-Method," was proposed to ACI 349 code committee by European researchers. After an extensive review of all available test data, in May 2000 the ACI 349 code committee issued a revised Appendix B that is based, in part, on the CC-Method.

Based on the developments discussed above, the staff maintains that endorsement of the latest version of Appendix B to ACI 349, supplemented with lessons learned from the resolution of USI A46, will result in better review guidance for the evaluation of steel embedments used to anchor component and structural supports to concrete.

2. OBJECTIVES

The objective of the regulatory action is to update NRC guidance on the design, analysis, and inspection of steel embedments used to anchor components and structural supports to concrete.

3. ALTERNATIVES AND CONSEQUENCES OF PROPOSED ACTION

3.1 Alternative 1 - Do not issue guidance on the design, analysis, and inspection of steel embedments used to anchor components and structural supports to concrete.

Under this alternative, guidance would not be issued and licensees would continue to rely on the criteria of IEB 79-02 and those used in the resolution of USI A-46. The staff acknowledges that, although the NRC has not formally endorsed Appendix B to ACI 349, licensees have submitted anchorage modifications with appropriate testing for review based on more recent editions of Appendix B. This alternative is considered the baseline or no action alternative.

3.2 Alternative 2 - Issue guidance on the design, analysis, and inspection of steel embedments used to anchor components and structural supports to concrete.

The staff has identified the following consequences associated with adopting Alternative 2.

3.2.1 Guidance will help to ensure that licensees will use the latest consensus standards available, thereby resulting in improved design, evaluation, and quality assurance of steel embedments used to anchor component and structural supports to concrete. For example, past seismic Probabilistic Risk Analysis (PRA) studies have often reported the anchorage of safety-related components to concrete as the controlling weak link that defined the seismic fragility of the component. In fact, anchorage was the controlling weak link used to define the seismic fragility for more than 50% of the passive components (cabinets, tanks, etc.) considered in past seismic PRA studies. Anchorage controlled the seismic fragility for several reasons: (1) variations in seismic design criteria used to design anchorages led to varying degrees of conservatism, (2) anchorage design criteria were based on a more limited amount of test data than now exists, (3) anchors were not designed with the same degree of seismic margin as the component being anchored, and (4) the as-built anchorage has sometimes differed in a detrimental manner from the as-designed anchorage.

The adoption and use of the proposed Appendix B anchorage provisions would substantially reduce the percentage of cases where anchorage controls seismic fragility, as a result of the first three of the above reasons. The fourth reason is expected to be controlled by improved quality assurance of anchorage in the installation and inspection of anchorages.

Appendix B anchorage provisions are based on a careful study of over 3000 anchorage tests. The proposed anchorage capacity formulas fit this test data with a lower coefficient of variation (COV) than do prior anchorage capacity formulas. This COV is typically about 0.2 or less, which is consistent with the COV obtained for other well defined concrete or steel failure mode capacities. Therefore, the level of conservatism introduced into the anchorage design is more uniformly controlled over a wide variety of cases. The net result would be a reduction in the likelihood that anchorage is the controlling weak link in the capacity of an anchored component.

The staff views the latest standard as improved because it is based on extensive test data and incorporates the latest technology and knowledge on the subject.

3.2.2 Guidance would promote regulatory efficiency by reducing uncertainty as to what is acceptable and by encouraging consistency in the design, evaluation, and quality assurance of steel embedments used to anchor component and structural supports to concrete. To the extent this occurs, it will result in potential benefits to both the NRC and industry. Published guidance should facilitate NRC review because licensee submittals should be more predictable and consistent analytically. Similarly, licensee's adherence to latest consensus standards should benefit licensees by reducing the likelihood for follow-up questions and possible revisions to licensees' plans.

3.2.3 Published guidance could result in cost savings to both the NRC and the industry. From the NRC's perspective, relative to the baseline, NRC would incur one-time incremental costs to develop the guidance for public comment and to finalize a regulatory guide. However, the NRC should also realize cost savings associated with the review of licensee submittals. In the staff's view, the continuous and on-going cost savings associated with these reviews should more than offset this one-time cost.

Similarly, on balance, it is expected that industry would realize a net savings as its one time incremental cost to review and comment on a regulatory guide would be more than compensated for by the efficiencies (e.g., reduced follow-up questions and revisions) associated with each licensee submittal.

3.2.4 The use of industry consensus standards, which are already being used by licensees, would enhance the continued use of the guidance contained in Appendix B, thereby avoiding costs related to a "new" agency-prepared standard. This approach would also comply with the Commission's directive that standards developed by consensus bodies be utilized per Public Law 104-113, “National Technology and Transfer Act of 1995.”

4. CONCLUSION

Based on this regulatory analysis, it is recommended that the NRC develop and issue guidance. The NRC staff concludes that the proposed action would reduce unnecessary burden on the part of both the NRC and its licensees, and it would result in an improved process for the design, evaluation, and quality assurance of steel embedments used to anchor component and structural supports to concrete. The staff sees no adverse effects associated with issuing guidance.

BACKFIT ANALYSIS

The regulatory guide does not require a backfit analysis as described in 10 CFR 50.109(c) because it does not impose a new or amended provision in the Commission’s rules or a regulatory staff position interpreting the Commission’s rules that is either new or different from a previous applicable staff position. In addition, this regulatory guide does not require the modification or addition to systems, structures, components, or design of a facility or the procedures or organization required to design, construct, or operate a facility. Rather, a licensee or applicant can select a preferred method for achieving compliance with a license or the rules or the orders of the Commission as described in 10 CFR 50.109(a)(7). This regulatory guide provides an opportunity to use industry-developed standards, if that is a licensee’s or applicant’s preferred method.