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Datum
25.05.2005

Proposed modifications to AC308 re: decreased temperatures, dated March 24, 2009 '

Dear Mr. Borchers:

According to the actual findings in Dr. Huelder's Phd-thesis the CAMA proposal as mentioned above is not sufficient to cover significant effects of the degree of curing on the behavior of adhesive anchors based on epoxy and epoxyacrylate resin. The tests by Huelder indicate that

+ the chemical resistance,
+ the creep behavior and
+ the glass transition and softening temperature

are significantly influenced by the degree of curing i.e. the temperature of the concrete member at time of installation.

Installation at low temperatures results in a reduced degree of curing even when the temperature is increased with time. With decreased degree of curing the glass transition temperature is decreased so that the behavior at increased temperature especially in case of sustained load is negatively influenced. Tests at decreased temperatures indicate that even if there is the same maximum load for tests with anchors installed at decreased temperature and reference tests at standard temperature the effect of the degree of curing is much more significant under sustained loading than under short term loading. An indication of the effect of the degree of curing on the behavior can be obtained during the first 100h to 200h of a sustained load test.

To take into account the actual findings with regard to the effect of the degree of curing on the behavior of adhesive anchors we have extended the modifications proposed by CAMA dated March 24, 2009. Our proposal is attached to this letter. The modifications are marked in red.

In the following the modified test program and their meaning are explained shortly:

- When bonded anchors are installed at low temperatures and the cartridge is preheated to make the injection of the mortar easier the ultimate capacity may decrease significantly (up to 1/3) compared to tests under the same conditions when the cartridge was at the low temperature of the concrete member and not preheated. The influence of the preheating of the cartridge on the ultimate capacity is product dependent.

  To check the influence of preheating of the cartridge on the bonded anchor behavior it is proposed to use cartridges, which are heated up to the maximum temperature allowed in the MPII, when installing anchors for the low temperature tests. This proposal is considered in the tests according to 9.6.2.1 to 9.6.2.4.

- In Sections 9.6.2.2 and 9.6.2.3 it is proposed that after curing at the low installation temperature the anchors are loaded with the load $N_{sust,lt}$ over 150h i.e. about 6 days before heating-up the concrete specimen. The constant load applied at low temperature might have a negative effect on the failure load at increased temperature due to the low degree of curing. A constant load applied to the anchor after installation in low temperature cannot be ruled out in practice.

  According to the current test procedure the specimen are heated up to standard temperature during 72h to 96h while the constant load is kept constant. It is proposed to add an additional test series in which the specimen is heated up to 110°F (43°C). In this test series the effect of a possible decrease of the glass transition temperature in the anchor is tested.

- Installation at decreased temperature results in a reduced degree of curing and in a reduction of the glass transition temperature. Currently creep tests at standard temperature are proposed. These tests are not considered as sufficient because at standard temperature a reasonable degree of curing is reached and the distance to the glass transition temperature is still large. Therefore it is proposed to perform additional two test series, see Section 9.6.2.4:

  In the first test series A the specimen are heated up to 110°F (43°C) and the creep test is performed. In this test series the influence of a possible reduction of the glass transition temperature on the anchor behavior is tested.

  In the second test series B the specimen is cooled to 40°F (5°C) and then a creep test is performed. In this test series the influence of a possible low degree of curing on the anchor behavior is checked.

- Currently we do not have results of creep tests with bonded anchors with a significantly reduced sustained load strength compared to the bond strength under short term loading. The reduction factor α_ρ evaluated in sustained load tests is in the order of 0.5 to 0.6 up to now. Therefore a lower limit of $\alpha_\rho = 0.4$ is proposed in Section 11.12.5. For lower values of $\alpha_\rho < 0.4$ the Findley-extrapolation might not be valid any more.

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- If in the test according to Section 9.6.2.4.4 the requirements on the extrapolated displacements or the residual capacity are not fulfilled, the tests must be repeated with a reduced sustained load and a reduction factor α_ρ must be evaluated. For anchors installed at low temperature the bond strength evaluated according to Eq. 11.12 shall be multiplied with the reduction factor α_{ct} according to Eq. 11.34c and the reduction factor α_ρ evaluated from the results of tests according to 9.6.2.4.4. The text has been changed accordingly in Sections 11.15.4.2 and 11.15.4.3

A detailed presentation on Dr. Huelder's Phd-thesis will be held at the next CAMA-meeting in Birmingham.

Please send this letter and the attachment to all CAMA members and representatives of ICC-ES for information.

Sincerely

(Rolf Eligehausen) (Werner Fuchs)

Encl.

Proposed modification to AC308 - *Acceptance Criteria for Post-Installed Adhesive Anchors in Concrete Elements* *amended by Rolf Eligehausen and Werner Fuchs, May 25, 2009*

Overview:
The proposed changes to AC308 noted below (optional test procedure for adhesive anchor systems that may not comply with Sections 9.6.2.2 and 11.15.2 of AC308) is to permit the recognition of adhesive anchor system that experience a reduction in performance when installed at decreased temperatures. The methodology employed in the test regime and assessment of the data is similar in scope and procedure to that utilized to determine the effects of elevated temperatures on cured adhesive anchor systems. Please note that all changes and additions to the criteria are presented in underline/strikeout format.

General question:
Does it make sense to distinguish between concrete temperatures less than 50°F (10°C) and below 40°F (5°C) since the installer does not make a difference within this range of temperature. However, he feels if it is beyond or below 40°F (5°C). This is not considered in the following amendments, however it is strongly recommended to stay with only the case of below 40°F (5°C).

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9.6 Tension tests with decreased installation temperature (Table 4.1, Test No. 8b; Table 4.2, Test No. 12b; Table 4.3, Test No. 12b; Table 4.4, Test No. 11b):

9.6.1 Purpose: These optional service-condition tests are used to assess the sensitivity of the adhesive material to installation in concrete having reduced temperature.

9.6.2 General test conditions:

9.6.2.1 Tests are confined tension tests performed in uncracked concrete for anchors to be installed in concrete having a temperature less than 50°F (10°C). Concrete test members shall have maximum dimensions 30 in. by 18 in. by 12 in. (760 mm by 460 mm by 300 mm). Alternatively, a 12-in. (300 mm) high cylinder with maximum diameter 13 in. (330 mm) may be used. Perform tests as follows:

(a) Prior to installation, condition the adhesive to 68°F ± 5°F (+20°C ± 2°C) or the maximum adhesive temperature given in the MPII and the anchor rod and test member to the target temperature (i.e., the lowest installation temperature recommended by the manufacturer) and maintain that temperature for a minimum of 24 hours.

(b) Install the anchors in the concrete test members of the target temperature and allow them to cure at the stabilized temperature for the cure time according to the manufacturer's printed installation instructions.

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(c) Immediately thereafter, remove the test members from the cooling chamber and tension test the anchors in order to assure the test members remain at the conditioned temperature. A thermocouple inserted into the test member may be used to confirm the temperature at the time of testing.

9.6.2.2 When anchors are recommended for installation in concrete temperatures below 40°F (5°C), the test series in 9.6.2.2.1, 9.6.2.2.2 and 9.6.2.2.3 shall be performed in uncracked concrete.

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9.6.2.2.1 Install and test a minimum of five (5) anchors as follows:

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(a) Prior to installation, condition the adhesive to 68°F ± 5°F (+20°C ± 2°C) or the maximum adhesive temperature given in the MPII and the anchor rod and test member to the target temperature (i.e., the lowest installation temperature recommended by the manufacturer) and maintain that temperature for a minimum of 24 hours.

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(b) Install the anchors in the concrete test members of the target temperature in accordance with the manufacturer's printed installation instructions and allow them to cure at the stabilized target temperature for the cure time according to the manufacturer's printed installation instructions.

(c) Immediately thereafter, apply a constant tension load $N_{sust,lt}$ as given by Eq. 8.3 and maintain $N_{sust,lt}$ over a minimum period of 150 hours.

(d) Raise the temperature of the test chamber at a constant rate to standard temperature over a period of 72 to 96 hours while monitoring the displacement response for each anchor. At no time may the test member be exposed to temperatures above standard temperature during this step. A thermocouple inserted into the test member may be used to confirm the temperature of the test members during the test.

(e) Once the test member attains standard temperature, conduct a confined tension test to failure with continuous measurement of load and displacement.

9.6.2.2.2 Install and test a minimum of five (5) anchors as follows:

(a) Prior to installation, condition the adhesive to 68°F ± 5°F (+20°C ± 2°C) or the maximum adhesive temperature given in the MPII and the anchor rod and test member to the target temperature (i.e., the lowest installation temperature recommended by the manufacturer) and maintain that temperature for a minimum of 24 hours.

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(b) Install the anchors in the concrete test members of the target temperature in accordance with the manufacturer's printed installation instructions and allow them to cure at the stabilized target temperature for the cure time according to the manufacturer's printed installation instructions.

(c) Immediately thereafter, apply a constant tension load $N_{sust,lt}$ as given by Eq. 8.3 and maintain $N_{sust,lt}$ over a minimum period of 150 hours.

(d) Raise the temperature of the test chamber at a constant rate to 110°F (43°C) over a period of 72 to 96 hours while monitoring the displacement response for each

anchor. A thermocouple inserted into the test member may be used to confirm the temperature of the test members during the test.

(e) Once the test member attains 110°F (43°C), conduct a confined tension test to failure with continuous measurement of load and displacement.

9.6.2.2.3 In addition, testing in accordance with 9.6.2.1 is to be conducted at the same temperature as the target temperature utilized in 9.6.2.2.

Add the following language to Section 9.6 :

9.6.2.3 When anchors are recommended for installation in concrete temperatures below 40°F (5°C) but do not fulfill the requirements of Sections 9.6.2.2 and 11.15.2, the test series in 9.6.2.3.1, 9.6.2.3.2 and 9.6.2.3.3 shall be performed in uncracked concrete.

9.6.2.3.1 Install and test a minimum of five (5) anchors in uncracked concrete as follows:

(a) Prior to installation, condition the adhesive to 68°F ± 5°F (+20°C ± 2°C) or the maximum adhesive temperature given in the MPII and the anchor rod and test member to the target temperature (i.e., the lowest installation temperature recommended by the manufacturer) and maintain that temperature for a minimum of 24 hours.

(b) Install the anchors in the concrete test members of the target temperature in accordance with the manufacturer's printed installation instructions and allow them to cure at the stabilized target temperature for the cure time according to the manufacturer's printed installation instructions.

(c) Immediately thereafter, apply a constant tension load $N_{sust,lt}$ as given by Eq. 8.3 and maintain $N_{sust,lt}$ over a minimum period of 150 hours.

(d) Raise the temperature of the test member to standard temperature over a period of 72 to 96 hours. At no time may the test member be exposed to temperatures above standard temperature during this step. A thermocouple inserted into the test member may be used to confirm the temperature of the test member during the test.

(e) Once the test member attains standard temperature, conduct a confined tension test to failure with continuous measurement of load and displacement.

9.6.2.3.2 Install and test a minimum of five (5) anchors as follows:

(a) Prior to installation, condition the adhesive to 68°F ± 5°F (+20°C ± 2°C) or the maximum adhesive temperature given in the MPII and the anchor rod and test member to the target temperature (i.e., the lowest installation temperature recommended by the manufacturer) and maintain that temperature for a minimum of 24 hours.

(b) Install the anchors in the concrete test members of the target temperature in accordance with the manufacturer's printed installation instructions and allow them to cure at the stabilized target temperature for the cure time according to the manufacturer's printed installation instructions.

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(c) Immediately thereafter, apply a constant tension load $N_{sust,lt}$ as given by Eq. 8.3 and maintain $N_{sust,lt}$ over a minimum period of 150 hours.
(d) Raise the temperature of the test chamber at a constant rate to 110°F (43°C) over a period of 72 to 96 hours while monitoring the displacement response for each anchor. A thermocouple inserted into the test member may be used to confirm the temperature of the test members during the test.
(e) Once the test member attains 110°F (43°C), conduct a confined tension test to failure with continuous measurement of load and displacement.

9.6.2.3.3 In addition, testing in accordance with 9.6.2.1 is to be conducted at the same temperature as the target temperature utilized in 9.6.2.3.

9.6.2.4 When anchors are recommended for installation in concrete temperatures below 40°F (5°C) but do not fulfill the requirements of Section 9.6.2.2 and 11.15.2, the sensitivity to sustained loads shall also be determined in the two (2) test series 9.6.2.4.4.1 and 9.6.2.4.4.2:

9.6.2.4.1 It is required to perform the tests in a concrete test member made from the same batch as the test member used for tests at decreased installation temperature in accordance with Section 9.6.2.3.

9.6.2.4.2 Perform sustained tension tests in uncracked concrete, followed by confined tension tests to failure.

9.6.2.4.3 Each test shall have a minimum duration of 42 days.

9.6.2.4.4 Perform the test series as follows:

9.6.2.4.4.1 Test series A:

(a) Install a minimum of five anchors in accordance with steps (a) and (b) of Section 9.6.2.3. After the curing period has elapsed, a tension preload not exceeding 5% of $N_{sust,lt}$ *or 200lbs* shall be applied to the anchor prior to zeroing displacement readings. Then increase the load on the anchor to a constant tension load $N_{sust,lt}$ as given by Eq. 8.3 multiplied by α_{ct} as given in Eq. 11.34c.
(b) Maintain load $\alpha_{ct} \cdot N_{sust,lt}$ and maintain temperature at target temperature (i.e., the lowest installation temperature recommended by the manufacturer). For tolerances on the temperature and the frequency of displacement monitoring see Section 8.18.3.
(c) To check the residual capacity after the sustained load, raise the temperature of the test member to standard temperature over a period of 72 to 96 hours. At no time may the test member be exposed to temperatures above standard temperature during this step. A thermocouple inserted into the test member may be used to confirm that test member is stabilized at standard temperature. Then unload the anchor and conduct a confined tension test to failure at standard temperature with continuous measurement of load and displacement.

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9.6.2.4.4.2 Test series B:

(a) Install a minimum of five anchors in accordance with steps (a) and (b) of Section 9.6.2.3. After the curing period has elapsed, a tension preload not exceeding 5% of $N_{sust,lt}$ *or 200lbs* shall be applied to the anchor prior to zeroing displacement readings. Then increase the load on the anchor to a constant tension load $N_{sust,lt}$ as given by Eq. 8.3 multiplied by α_{ct} as given in Eq. 11.34c.

(b) Raise the temperature of the test member to 110°F (43°C) over a period of 72 to 96 hours. A thermocouple inserted into the test member may be used to confirm that test member is stabilized at 110°F (43°C). Maintain load $\alpha_{ct} \cdot N_{sust,lt}$ and temperature at 110°F (43°C) over the test period. For tolerances on the temperature and the frequency of displacement monitoring see Section 8.18.3.

(c) To check the residual capacity after the sustained load unload the anchor and conduct a confined tension test at 110°F (43°C) to failure with continuous measurement of load and displacement.

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Gelöscht: 9.6.2.4.7 To check the remaining load capacity after the sustained load test, unload the anchor and carry out a confined tension test at standard temperature.¶

In section 11.12.2, under Eq. 11.32, modify the definition of $t_{service}$ with the following:

$t_{service}$ = the intended anchor service life (hours)

= 50 years (standard temperature conditions and decreased installation temperature)

= 10 years (elevated temperature conditions)

Modify section 11.12.3 as follows:

11.12.3 The mean values of the extrapolated estimates of the total displacement over the anchor intended service life $\Delta_{service}$ shall not exceed Δ_{lim} where Δ_{lim} is the mean displacement corresponding to the loss of adhesion N_{adh} for adhesive anchors (see Section 11.3.4 and Fig. 11.1 through Fig. 11.4) or to uncontrolled slip $N_{1,x}$ for torque-controlled adhesive anchors (see Section 11.4.6 and Fig. 11.5) as measured in corresponding ~~reference~~ tensile tests. ~~at standard temperature and maximum long-term elevated temperature, respectively.~~

11.12.3.1 For $\Delta_{service}$ at standard temperature, Δ_{lim} shall be determined from standard temperature reference tests (see Section 7.0).

11.12.3.2 For $\Delta_{service}$ at long-term elevated temperature, Δ_{lim} shall be determined from maximum long-term elevated temperature service-condition tests (see Section 9.5).

11.12.3.3 For $\Delta_{service}$ for decreased installation temperature, Δ_{lim} shall be determined from decreased installation temperature reliability tests (see Section 9.6.2.3.1).

Modify section 11.12.5 as follows:

11.12.5 If the requirements on displacement are not met, repeat the sustained load tests with a reduced sustained load until the requirements are met and evaluate the reduction factor α_{ρ} in accordance with Section 11.3.7 or Section 0. The value α_{ρ} shall be greater than 0.40.

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11.15 Assessment of performance with decreased installation temperature for adhesive and torque controlled adhesive anchors:

11.15.1 For anchors recommended for installation in concrete temperatures below 50°F (10°C), the mean and the 5% fractile of the failure loads associated with the reduced temperature installation shall equal or exceed ~~(or be shown to be statistically equivalent to)~~ the mean and the 5% fractile of the corresponding reference tests. Alternatively, the failure load associated with the reduced temperature installation shall be shown to be statistically equivalent to the failure load associated with the corresponding reference test.

11.15.1.1 Comparison of the 5% fractile values may be omitted if either of the following conditions is met:

1. For both test series, the coefficient of variation of the failure loads is $v \leq 10\%$.

2. The difference in the number of tests in each series is $\Delta n \leq 5$ and the coefficient of variation of the temperature test series is equal to or less than the coefficient of variation of the reference test series.

11.15.2 For anchors recommended for installation in concrete temperatures below 40°F (5°C), and tested in accordance with 9.6.2.2, the conditions of Section 11.15.1 shall be fulfilled. In addition, the displacement of the anchor under sustained load just prior to tension testing to failure shall stabilize to the degree that an assessment can be made that failure is unlikely to occur.

11.15.3 Anchors that do not fulfill the requirements for a given target temperature shall be retested at a temperature at which the requirements are fulfilled. The temperature at which the requirements are fulfilled shall be reported as the minimum concrete temperature at the time of installation.

11.15.4 For anchors where the lowest installation temperature recommended by the manufacturer is below 40°F (5°C), and testing in accordance with 9.6.2.3 and 9.6.2.4 has

been conducted, tension test results associated with reduced temperature installation in accordance with tensile testing in 9.6.2.1 and 9.6.2.3 are used to calculate α_{ct} using Eq. 11.34c.

For testing in accordance with 9.6.2.1,

$$\alpha_{ct1} = \min\left[\frac{\overline{N}_{ct}}{\overline{N}_o}; \frac{N_{k,ct}}{N_{k,o}}\right] \le 1.0 \qquad \text{Eq. 11.34a}$$

For testing in accordance with 9.6.2.3,

$$\alpha_{ct3} = \min\left[\frac{\overline{N}_{ct}}{\overline{N}_o}; \frac{N_{k,ct}}{N_{k,o}}\right] \le 1.0 \qquad \text{Eq. 11.34b}$$

α_{ct3} according to Eq. 11.34b shall be calculated from the results of tests according 9.6.2.3.1. and 9.6.2.3.2. The lowest value of α_{ct3} is decisive.

$$\alpha_{ct} = 0.80 \le \min[\alpha_{ct1}; \alpha_{ct3}] \le 1.0 \qquad \text{Eq. 11.34c}$$

11.15.4.1 Comparison of the 5% fractile values may be omitted if either of the following conditions is met:

1. For both test series, the coefficient of variation of the failure loads is $v \le 10\%$.

2. The difference in the number of tests in each series is $\Delta n \le 5$ and the coefficient of variation of the temperature test series is equal to or less than the coefficient of variation of the reference test series.

11.15.4.2 For anchors meeting the requirements of 11.15.1 at a temperature above the minimum installation temperature recommended in the MPII, the bond strength calculated according to Eq. 11.12 shall be multiplied with the reduction factor determined by Eq. 11.34c for anchors installed at temperatures below the temperature at which the requirements of 11.15.1 were fulfilled or 40°F (5°C), whichever is higher.

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11.15.2.3 For anchors unable to meet the requirements of 11.15.1, the bond strength calculated according to Eq. 11.12 shall be multiplied with the reduction factor determined by Eq. 11.34c and the reduction factor $\alpha_{p,}$ evaluated from the results of tests according to 9.6.2.4.4 for anchors installed at temperatures below 50°F (10°C).

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Additional changes to other sections of the Criteria:

Section 2.2.1: Add the following notations,

$\overline{N}_{ct}$ = mean tension capacity of an anchor when cured at decreased installation temperature, see Section 11.15.4, lb (N).

$N_{k,ct}$ = characteristic tension capacity of an anchor when cured at decreased installation temperature, see Section 11.15.4, lb (N).

α_{ct1} = reduction factor for decreased installation temperature from testing per 9.6.2.1 in accordance with Eq. 11-34a

α_{ct3} = reduction factor for decreased installation temperature from testing per 9.6.2.3 in accordance with Eq. 11-34b

α_{ct} = reduction factor for decreased installation temperature in accordance with Eq. 11-34c

Section 11.3.5.3.2: Add α_{ct} as a multiplication factor in Eq. 11.12, as follows:

$$\tau_{k(cr,uncr)} = \tau_{k,nom(cr,uncr)} \cdot \beta \cdot \alpha_{lt} \cdot \alpha_{st} \cdot \alpha_{dur} \cdot \alpha_{\rho} \cdot \alpha_{conc} \cdot \alpha_{cov} \cdot \alpha_{cat3} \cdot \underline{\alpha_{ct}} \text{ psi (MPa)} \qquad \text{Eq. 11.12}$$

Add the following notation to the comments below Eq. 11.12:

α_{ct} = reduction factor for decreased installation temperature, see Eq. 11.34c.

Section 11.4.8.1: Add α_{ct} as a multiplication factor in Eq. 11.23, as follows:

$$N_{k,p(cr,uncr)} = N_{k,p,nom(cr,uncr)} \cdot \beta \cdot \alpha_{lt} \cdot \alpha_{st} \cdot \alpha_{dur} \cdot \alpha_{\rho} \cdot \underline{\alpha_{ct}} \text{ lb (N)} \qquad \text{Eq. 11.23}$$

Add the following notation to the comments below Eq. 11.23:

α_{ct} = reduction factor for decreased installation temperature, see Eq. 11.34c.

Renumbering of equations after 11.34 will be required.