

Low-carbon concrete building code v 7.1

Commentary language in red. Administrative language is specific to Marin County, California; other jurisdictions must adapt and adjust as needed.

Summary of update: With this version 7, limit values are proposed in Table 19.07.050.1. These limits are intended to be ambitious in reducing emissions while still practicable—not imposing excessive burden on stakeholders. They key off of national averages published in 2014 by the National Ready Mixed Concrete Association (NRMCA), though not uniformly. For lesser strength concretes ($f'_c < 3,000$ psi), we use 90% of the NRMCA values, while for higher strength concretes, presumed to be supplied by more sophisticated producers who have more capacity to innovate, we use 80% of NRMCA values at 4000 psi and 70% of NRMCA values at 5000 psi and greater.

The longer-term goal is to bring the concrete industry into alignment with announced emission reduction goals of multiple relevant government and trade bodies, such as:

- 1) The State of California e.g., the Global Warming Solutions Act (AB32) of 2006, and Buy Clean California (AB 262) of October 15, 2017;
- 2) The American Institute of Architects and Architecture 2030 (The 2030 Challenge);
- 3) The Structural Engineering Institute (SE 2050 Initiative)
- 4) The County of Marin (Drawdown: Marin climate action plan)
- 5) World Cement Association (Climate Action Plan)

To meet a goal of zero emissions by 2050, reductions imposed by code would have to ratchet down concrete emissions on a schedule something like the following (based on 2014 NRMCA values):

| | | |
|------|------|--|
| 2020 | 10% | (current proposal) |
| 2023 | 18% | |
| 2026 | 26% | |
| 2029 | 34% | |
| 2032 | 45% | |
| 2035 | 56% | |
| 2038 | 67% | |
| 2041 | 78% | |
| 2044 | 85% | |
| 2047 | 93% | |
| 2050 | 100% | (requiring zero carbon technologies we have yet to invent) |

This draft 7.0 is being widely distributed to provide stakeholders and other interested parties time to comment prior to a stakeholder meeting scheduled for July 17, 2019 in San Francisco.

Code language and limits will be finalized at that meeting.

Chapter 19.07 is added to Marin County Code, as follows:

19.07 - REDUCED CARBON CONCRETE REQUIREMENTS

Express finding: Pursuant to Section 17958.2(a) of the California Health and Safety Code, the Marin County Board of Supervisors hereby finds the following modifications to the 2019 California Building Code Section 1901.2 and 2019 California Residential Code Sections R402.2.1, R404.1.3, R506.1 and R608.5, as shown in Sections 19.07.040 regulating allowable mix design and materials for plain and reinforced concrete, are reasonably necessary. This is because the County of Marin is bordered by sea water on three sides and subject to direct adverse local impact from sea-level rise as the result of construction-related contributions to climate change, significantly including carbon emissions from cement production.

Marin County, like most jurisdictions in North America, has great leeway in modifying or adding amendments to the template code, in this case being the California Building code which in turn is based on the International Building Code. Both law and common sense dictate that the County should state its particular reasons (findings) for the amendment/addition.

19.07.010 – Purpose

The purpose of this chapter is to provide practical standards and requirements for the composition of concrete, as defined herein, for all construction and paving purposes, that maintains adequate strength and durability for the intended application and at the same time reduces greenhouse gas emissions associated with the concrete composition.

19.07.020 – Definitions

For the application of this chapter the following definitions shall apply:

Concrete – Any approved combination of mineral aggregates bound together into a hardened conglomerate in accordance with the requirements of this code.

Environmental Product Declaration (EPD) Environmental Product Declarations present quantified environmental information on the life cycle of a product to enable comparisons between products fulfilling the same function.

Global Warming Potential (GWP) is the total greenhouse gas emissions resulting from the extraction, manufacture and delivery of a material or product into its service form.

These definitions are generally taken from or repeat definitions provided by the International Standards Organization, ISO. Some additional useful definitions are:

Carbon Dioxide Equivalent or **CO₂ equivalent** or **CO₂e** unit for comparing the radiative forcing of a greenhouse gas to that of carbon dioxide.

Embodied Carbon – Informally used for "Global Warming Potential"

Global Warming Potential (GWP) is also sometimes informally called "embodied carbon" aka "carbon footprint". Global warming potential is also used outside of these provisions as a characterization factor describing the radiative forcing impact of one mass-based unit of a given greenhouse gas relative to that of carbon dioxide over a given period of time, used to calculate Carbon Dioxide Equivalent.

Greenhouse Gas (GHG) gaseous constituent of the atmosphere that absorbs and emits radiation at specific wavelengths within the spectrum of infrared radiation emitted by the earth's surface, the atmosphere, and clouds.

Greenhouse Gas Emission mass of a greenhouse gas released to the atmosphere.

19.07.030 – Scope

The requirements of this chapter shall apply to all plain and reinforced concrete installed within the unincorporated areas of Marin County.

After some debate, the committee decided to not recommend (for now) to try to apply this code to precast concrete or to manufactured concrete such as cement masonry units (CMU) or other structural or non-structural building materials in order to simplify the policy for initial adoption and implementation.

19.07.040 – California Building Standards Code amendments

Section 1901.2 of the 2019 California Building Code is hereby amended to add the following language to the end of the first sentence: "and Chapter 19.07 of Marin County Code".

Section R402.2.1 of the 2019 California Residential Code is hereby amended to add the following language to the end of the first sentence: ", as amended by Chapter 19.07 of Marin County Code".

Section R404.1.3 of the 2019 California Residential Code is hereby amended to add the following language to the end of the first sentence: ", as amended by Chapter 19.07 of Marin County Code".

Section R404.1.3 of the 2019 California Residential Code is hereby amended to add the following language to the end of the second sentence: ", as amended by Chapter 19.07 of Marin County Code".

Section R404.1.3 of the 2019 California Residential Code is hereby amended to add the following language to the end of the third sentence: ", as amended by Chapter 19.07 of Marin County Code".

Section R404.1.3 of the 2019 California Residential Code is hereby amended to replace the language of the fourth sentence as follows: "When ACI 318, ACI 332, PCA 100 or the provisions of this section, as amended by Chapter 19.07 of Marin County Code, are used to design concrete foundation walls, project drawings, typical details and specifications

are not required to bear the seal of the architect or engineer responsible for design, unless otherwise required by the state law of the jurisdiction having authority."

Section R506.1 of the 2019 California Residential Code is hereby amended to add the following language to the end of the first sentence: ", as amended by Chapter 19.07 of Marin County Code".

Section R608.5 of the 2019 California Residential Code is hereby amended to add the following language to the end of the first sentence: ", as amended by Chapter 19.07 of Marin County Code".

19.07.050 – Compliance

Compliance with the requirements of this chapter shall be demonstrated to the chief building official through any of the compliance options of this section.

| | Cement limits for use with prescriptive compliance methods 19.07.050.1 and 19.07.050.2 | GWP limits for use with performance compliance methods 19.07.050.3 and 19.07.050.4 |
|---|--|---|
| Minimum specified compressive strength f'_c , psi (5) | Maximum ordinary Portland cement content, lbs/yd ³ (1, 2, 4) | Maximum Global Warming Potential, GWP, kg CO ₂ e /m ³ |
| up to 2500 (3,4) | 362 | 260 |
| 2501 to 3000 | 410 | 289 |
| 3001 to 4000 | 456 | 313 |
| 4001 to 5000 | 503 | 338 |
| 5001 to 6000 | 531 | 356 |
| 6001 to 7000 | 594 | 394 |
| 7001 and higher | 657 | 433 |
| up to 3000 light weight | 512 | 578 |
| 3001--4000 light weight | 571 | 626 |
| 4001--5000 light weight | 629 | 675 |

Table 19.07.050.1 – Cement and GWP limitations

Notes

- (1) Portland cement of any type per ASTM C150. The maximum cement content may be increased proportionately above the tabulated value when using an approved cement, or blended cement, demonstrated by approved EPD to have a plant-specific global warming potential (GWP_{PS}) lower than 1040 kg CO₂e/metric ton. The increase in allowable cement content would be $(1040 / \text{GWP}_{PS}) \%$.

(1040 kg CO₂e/metric ton is the industry average most recently published by the Portland Cement Association (PCA).)

Example 1: A blended cement with an established GWP_{PS} of 900 kg. CO₂e/metric ton is used for a 3,000 psi concrete mix, so the maximum allowable amount of cement then becomes:

$$(1040/900) \times 410 = 474 \text{ lbs per cubic yard}$$

- (2) Cement or GWP limits shown can be increased by 10% for concretes demonstrated to the Building Official as requiring high early strength. Such concretes could include:

- Precast, prestressed concrete
- Beams and slabs above grade

Is 10% the right allowance?

c. Retaining walls requiring immediate backfill

- (3) Concrete with designated strength less than 2500 psi is not subject to minimum strength and reinforcing limitations of ACI 318.
- (4) Concrete using clay, or both clay and cement, as binder shall be designed and constructed consistent with successful historical precedent or substantiated by test data, and is subject to approval by the Building Official. Clay-based concrete systems, historically known as earthen construction, include adobe (unfired earth) blocks, compressed earth blocks, cob (or *puddled earth*), and rammed earth. Concrete using both clay and cement, historically known as soil-cement, include roller-compacted concrete or road base, stabilized rammed earth, and stabilized earth block.
- (5) The permit applicant must designate the time allotted for a concrete mix to reach its minimum specified compressive strength, be it 28, 56, 84 days or more.
- (6) The maximum cement content may be increased by 10% above the tabulated value for concrete mixes for which the coarse aggregate is at least 50% reclaimed concrete, and/or is comprised of synthetic limestone aggregate manufactured primarily from carbon emissions.

Is 10% the right allowance?

Example 2: A hillside residence will be built requiring 4500 psi concrete. The concrete doesn't need to attain full strength for many months, however, so a mix design is chosen that has 500 lbs. of cement and 400 lbs. of slag as binder, which is known to reach 3800 psi at 28 days, and 4500 psi after 56 days. Table 19.07.050.1 sets a limit of 647 lbs. of cement per cubic yard, for which the mix easily complies.

19.07.050.1 Prescriptive Method – Cement content of a concrete mix using this method shall not exceed the value shown in the Table 19.07.050.1. Use of this method is limited to concrete with specified compressive strength not exceeding 5,000 psi.

19.07.050.2 Prescriptive Method--Project – Total cement content shall be based on total cement usage of all concrete mix designs within the same project. Total cement content for a project shall not exceed the value calculated according to Equation 19.07.050.2.

Equation 19.07.050.2:

$$Cem_{proj} < Cem_{allowed}$$

where

$$Cem_{proj} = \sum Cem_n v_n \quad \text{and} \quad Cem_{allowed} = \sum Cem_{lim} v_n$$

and

n = the total number of concrete mixtures for the project

Cem_n = the cement content for mixture n , kg/m³ or lb/yd³

Cem_{lim} = the maximum cement content for mixture n

per Table 19.07.050.1, kg/m³ or lb/yd³

v_n = the volume of mixture n concrete to be placed, yd³ or m³

Applicant can use yd³ or m³ for calculation, but must keep same units throughout

19.07.050.3 Performance Method--Mix Global Warming Potential of a concrete mix, based on an approved environmental product declaration (EPD), shall not exceed the value given in Table 19.07.050.1.

19.07.050.4 Performance Method--Project Total GWP (GWP_{proj}) of all concrete mix designs within the same project shall not exceed the project limit ($GWP_{allowed}$) determined using Table 19.07.050.1 and Equation 19.07.050.3.

Equation 19.07.050.3: $GWP_{proj} < GWP_{allowed}$

where

$$GWP_{proj} = \sum GWP_n v_n \quad \text{and} \quad GWP_{allowed} = \sum GWP_{lim} v_n$$

and

n = the total number of concrete mixtures for the project

GWP_n = the global warming potential for mixture n per mixture EPD, kg/m^3

GWP_{lim} = the global warming potential limit for mixture n
per table 19.07.050.1, kg/m^3

v_n = the volume of mixture n concrete to be placed, yd^3 or m^3

Applicant can use yd^3 or m^3 for calculation, but must keep same units throughout

Example 3: A "Five over One" podium building is planned for an urban block: five wood-framed stories of apartments over a post-tensioned slab on concrete columns and shearwalls on a mat slab parking garage.



Mix 1: Post-tensioned slab

90 cubic yards @ $f'_c = 6,000$ psi
GWP (from EPD) = 475

Mix 2: Walls and columns

60 cubic yards @ $f'_c = 5,000$ psi
GWP (from EPD) = 340

Mix 3: Mat foundation

200 cubic yards @ $f'_c = 3,000$ psi
GWP (from EPD) = 240

1. Calculate the total project GWP

$$\begin{aligned} GWP_{proj} &= (90 \times GWP_1) + (60 \times GWP_2) + (200 \times GWP_3) \\ &= (90 \times 475) + (60 \times 340) + (200 \times 240) \\ &= 111,150 \end{aligned}$$

2. Calculate the allowed GWP limit Use 10% allowable increase for Mix 1

$$\begin{aligned} GWP_{allowed} &= (90 \times GWP_{mix1} \times 1.1) + (60 \times GWP_{mix2}) + (200 \times GWP_{mix3}) \\ &= (90 \times 457 \times 1.1) + (60 \times 355) + (200 \times 289) \\ &= 124,343 > 111,150 \text{ project complies} \end{aligned}$$

19.07.060 – Verification and Enforcement

As a condition prior to the issuance of every building permit involving placement of concrete, the permit applicant shall be required to submit a completed Reduced Carbon Concrete Compliance Declaration on a form that shall be provided by the chief building official and reviewed for compliance by the building department prior to issuing the permit.

As a condition of such building permits prior to providing construction inspections following placement of concrete, the permit applicant shall be required to submit batch certificates and EPDs provided by the concrete provider that demonstrates compliance with the Reduced Carbon Concrete Compliance Declaration on file with the building permit. The batch certificates and EPDs shall be reviewed for compliance by the building department prior to allowing any further inspections to be scheduled.

For projects involving placement of concrete by, or on behalf of, a public works, parks, or similar department the director of such department, or his/her assignee, shall maintain accurate records of the total volume (in cubic yards) of all concrete placed, as well as the total compliant volume (in cubic yards) of all concrete placed, and shall report this data annually to the governing body in a form expressing an annual compliance percentage derived from the quotient of total compliant concrete volume placed divided by total concrete volume placed.

When deviations from compliance with this section occur the chief building official is authorized to require evidence of equivalent carbon reductions from the portions of remaining construction of the project to demonstrate alternative compliance with the intent of this chapter.

19.07.070 – Exemptions

1. Hardship or infeasibility exemption If an applicant for a covered project believes that circumstances exist that make it a hardship or infeasible to meet the requirements of this chapter, the applicant may request an exemption as set forth below. In applying for an exemption, the burden is on the applicant to show hardship or infeasibility.

Application. The applicant shall identify in writing the specific requirements of the standards for compliance that the project is unable to achieve and the circumstances that make it a hardship or infeasible for the project to comply with this chapter. The applicant may not petition for relief from any requirement of the 2019 California Energy Code (Title 24, Part 6) and referenced standards, or the 2019 California Green Building Standards (Title 24, Part 11) of the California Building Standards Code. Circumstances that constitute hardship or infeasibility shall include, but are not limited to the following:

- a. There is a conflict between the provisions of an applicable green building rating system or the California Building Standards Code, other state code provisions, other requirements of this title or conditions imposed on the project through a previously approved planning application;
- b. There is a lack of commercially available material necessary to comply;

- c. The cost of achieving compliance is disproportionate to the overall cost of the project;
- d. Compliance with certain requirements would impair the historic integrity of buildings listed on a local, state or federal list or register of historic structures as regulated by the California Historic Building Code (Title 24, Part 8).

(2) Granting of exemption If the chief building official determines that it is a hardship or infeasible for the applicant to fully meet the requirements of this chapter and that granting the requested exemption will not cause the building to fail to comply with the 2019 California Energy Code (Title 24, Part 6) and referenced standards, or the 2019 California Green Building Standards (Title 24, Part 11) of the California Building Standards Code, the chief building official shall determine the maximum feasible threshold of compliance reasonably achievable for the project. In making this determination, the chief building official shall consider whether alternate, practical means of achieving the objectives of this chapter can be satisfied. If an exemption is granted, the applicant shall be required to comply with this chapter in all other respects and shall be required to achieve the threshold of compliance determined to be achievable by the chief building official.

(3) Denial of exception If the chief building official determines that it is reasonably possible for the applicant to fully meet the requirements of this chapter, the request shall be denied and the applicant shall be notified of the decision in writing. The project and compliance documentation shall be modified to comply with the standards for compliance.

(4) Appeal Any aggrieved applicant or person may appeal the determination of the chief building official regarding the granting or denial of an exemption or compliance with any other provision of this chapter. An appeal of a determination of the chief building official shall be filed in writing and processed in accordance with the provisions of Section 19.04.028 of this code.