# Trends in Total Cementitious Content of State DOT Concrete Paving Mixtures

IOWA STATE UNIVERSITY
Institute for Transportation

DECEMBER 2024

National Concrete Pavement Technology Center
CP Tech Center

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## Reference Information for this Document

Lopez, S., J. Stempihar, J. Karam, and T. Van Dam. 2024. *Trends in Total Cementitious Content of State DOT Concrete Paving Mixtures*. National Concrete Pavement Technology Center, Iowa State University, Ames, IA.

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## Technical Report Documentation Page

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. | |
|---|---|---|---|
| **4. Title and Subtitle**<br>Trends in Total Cementitious Content of State DOT Concrete Paving Mixtures | | **5. Report Date**<br>December 2024<br>**6. Performing Organization Code** | |
| **7. Author(s)**<br>Sarah Lopez, Jeff Stempihar, and Jolina Karam, NCE; Thomas Van Dam, Wiss, Janney, Elstner Associates, Inc. | | **8. Performing Organization Report No.** | |
| **9. Performing Organization Name and Address**<br>National Concrete Pavement Technology Center<br>Iowa State University<br>2711 South Loop Drive, Suite 4700<br>Ames, IA 50010-8664 | | **10. Work Unit No.**<br>**11. Contract or Grant No.**<br>Part of Cooperative Agreement 693JJ31950004, Advancing Concrete Pavement Technology Solutions | |
| **12. Sponsoring Organization Name and Address**<br>Federal Highway Administration<br>1200 New Jersey Avenue, SE<br>Washington, DC 20590 | | **13. Type of Report and Period Covered**<br>Technical Summary<br>**14. Sponsoring Agency Code** | |
| **15. Supplementary Notes**<br>Visit https://cptechcenter.org for color pdfs of this and other research publications. The FHWA Contracting Officer was Robert Spragg. | | | |
| **16. Abstract**<br>Portland cement is a key component of concrete paving mixtures, but its production is a significant contributor to greenhouse gas (GHG) emissions. Since the late 1990s, state departments of transportation (DOTs) and the concrete paving industry have endeavored to reduce the amount of portland cement in concrete paving mixtures in order to improve performance while reducing costs, and this effort has recently regained attention as it is an important pathway to reducing the carbon footprint of paving mixtures. Over the same period, cement manufacturing has become more efficient, thus reducing the GHG emissions associated with production.<br>As a result of these trends, it has been asserted that the concrete paving industry has made progress over the past few decades in reducing the GHG emissions associated with paving concrete through a reduction in the amount of portland cement in the cementitious binder and by reducing the total cementitious content in paving concrete. To investigate this assertion, available data from the Long-Term Pavement Performance (LTPP) database, select state DOTs, the Federal Highway Administration's (FHWA's) Mobile Concrete Technology Center (MCTC), and the National Concrete Pavement Technology Center (CP Tech Center) at Iowa State University were compiled and reviewed. This document examines and summarizes these data. Data to support this assertion are limited and, at times, conflicting. The available data suggest that portland cement usage has remained about the same or possibly increased slightly since the late 1990s. | | | |
| **17. Key Words**<br>cementitious materials content—concrete pavement mixtures—greenhouse gas emissions—reduced-carbon paving materials—total cementitious content | | **18. Distribution Statement**<br>No restrictions. | |
| **19. Security Classification (of this report)**<br>Unclassified. | **20. Security Classification (of this page)**<br>Unclassified. | **21. No. of Pages**<br>14 | **22. Price**<br>NA |

**Form DOT F 1700.7 (8-72)** **Reproduction of completed page authorized**

# Acknowledgments

The authors would like to thank the Federal Highway Administration (FHWA) for sponsoring this research as part of Cooperative Agreement 693JJ31950004, Advancing Concrete Pavement Technology Solutions, Work Order 6.

The authors would also like to thank the following individuals and agencies that provided data: Jagan Gudimettla (FHWA Mobile Concrete Technology Center), Todd Hanson (Iowa Department of Transportation), Leif Wathne (National Concrete Pavement Technology Center), Angela Folkestad (Colorado/Wyoming Chapter, American Concrete Pavement Association), John Becker (Pennsylvania Chapter, American Concrete Pavement Association), and Abraham Abdulnour (Arizona Department of Transportation).

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# Executive Summary

This document presents available (historical) data on trends in total cementitious content in department of transportation (DOT) paving mixtures and explores progress the industry has made over the past few decades in reducing total portland cement content in concrete pavement mixtures, thus reducing greenhouse gas (GHG) emissions.

Portland cement is a key component of concrete paving mixtures, but its production is a significant contributor to US GHG emissions, accounting for approximately 1.1% of GHG emissions annually (EPA 2023). Since the late 1990s, state DOTs and the concrete paving industry have endeavored to reduce the amount of portland cement in concrete paving mixtures. However, this effort was not initiated with the goal of reducing GHG emissions but rather to create more economical and durable concrete mixtures. Research at the time showed that replacing a portion of portland cement with supplementary cementitious materials (SCMs) improved concrete durability (i.e., made the concrete less permeable and improved resistance to alkali-silica reactivity and sulfate attack). Further, reducing the total cementitious materials content of the concrete reduces the total paste volume if the water-to-cementitious materials ratio is kept constant, thus reducing drying shrinkage. The effort to reduce the portland cement content in concrete has recently regained attention with the recognition that it is an important pathway to reducing the carbon footprint of paving mixtures. The two main strategies of this pathway are to replace portland cement with suitable SCMs and/or ground limestone and to reduce the total cementitious content in concrete paving mixtures through the use of well-graded aggregate combinations.

Over the same period (since the 1990s), cement production has become more efficient due largely to economic drivers that have reduced energy demands, thus reducing the GHG emissions associated with production. In recent years (particularly since 2020), cement manufacturers have begun large-scale production of portland-limestone cement (PLC) specifically to reduce GHG emissions, increasing the amount of limestone interground with clinker from 3% to 4% up to 8% to 12% percent.

As a result of these trends, it is asserted that the industry has made progress over the past few decades in reducing the GHG emissions associated with paving concrete through a reduction in the amount of portland cement in the cementitious binder and by reducing the total cementitious content in paving concrete. Available data from the Long-Term Pavement Performance (LTPP) database, select state DOTs, the Federal Highway Administration's (FHWA's) Mobile Concrete Technology Center (MCTC), and the National Concrete Pavement Technology Center (CP Tech Center) at Iowa State University were compiled and reviewed. Data to support this assertion are limited and, at times, conflicting. The available data suggest that portland cement usage has remained about the same or possibly increased slightly since the late 1990s. Some key observations from the data review include the following:

- The state DOTs contacted for this analysis appear not to keep detailed concrete mixture proportion records over time, specifically records related to total cementitious and portland cement contents. Some agencies had information on general trends in cementitious content over the years.
- The data reviewed do not support the assertion that reduced-carbon concrete mixtures are currently being routinely placed by contractors, even when agencies permit lower total cementitious content in their specifications. In fact, one state reported that the total amount of cementitious content has increased in recent years.
- Data from the FHWA MCTC include 9 mixtures from 1999 to 2004 with an average total cementitious content of 580.3 lb/yd$^3$ and 30 mixtures from 2011 to 2022 with an average total cementitious content of 573.7 lb/yd$^3$. This represents a minimal reduction in total cementitious content between the early 2000s and 2010s/early 2020s.

It appears that some DOT specifications may remain a barrier to the adoption of reduced-carbon concrete mixtures. Yet contractors appear not to be taking full advantage of the portland cement reductions allowed by DOT specifications. The latter could be related to several minimum strength requirements embedded within the specifications for opening a paving lane to construction traffic or other construction activities (e.g., drilling in tie/dowel bars) or monetary risk associated with not meeting strength requirements.

# Introduction

Portland cement is a key component of concrete paving mixtures, but its production is a significant contributor to US greenhouse gas (GHG) emissions, accounting for approximately 1.1% of GHG emissions annually (EPA 2023). About 90% of these emissions can be attributed to portland cement production, which involves heating raw materials in a rotary kiln to high temperatures (~1,850°C). During this process, limestone (predominately calcium carbonate [CaCO3]) undergoes calcination and is decomposed into calcium oxide (CaO) and carbon dioxide (CO2). The calcination reaction alone is responsible for roughly 46% of the GHG emissions associated with concrete at the gate of the concrete plant, and another 37% of the total GHG emissions are from the fuel burned to achieve these high temperatures (Choate 2003). The calcination process in the kiln produces hard, dark nodules called clinker, which are then ground with calcium sulfate (commonly gypsum) and other minor additives to create portland cement.

Since the late 1990s, state departments of transportation (DOTs) and the concrete paving industry have endeavored to reduce the amount of portland cement in concrete paving mixtures. However, this effort was not initiated with the goal of reducing GHG emissions but instead focused on creating more economical and durable concrete. Research at the time clearly showed that replacing a portion of portland cement with supplementary cementitious materials (SCMs) increased concrete durability (i.e., made the concrete less permeable and improved resistance to alkali-silica reactivity and sulfate attack). Further, reducing the total cementitious materials content of the concrete reduces the total paste volume (at a given water-to-cementitious materials [w/cm] ratio), reducing drying shrinkage. The effort to reduce the portland cement content in concrete has recently regained attention with the recognition that it is an important pathway to reducing the carbon footprint of paving mixtures. The two main strategies of this pathway to lower carbon mixtures include replacing portland cement with suitable SCMs and/or ground limestone and reducing the total cementitious content in concrete paving mixtures through the use of well-graded aggregate combinations.

It has been asserted that since the late 1990s, state DOTs have reduced the GHG emissions of paving concrete by reducing the amount of portland cement in concrete paving mixtures, replacing more of it with SCMs and ground limestone, and reducing the total cementitious content of the concrete. However, a comprehensive dataset to support this assertion is not readily available. Concrete mixture designs reviewed as part of various applied research projects over the past few years still show mixtures having relatively high cementitious materials contents, with some achieving 28-day strength requirements in 7 days or less.

State DOT specifications play a major role in this outcome because they specify the requirements a contactor needs to meet for payment (e.g., minimum cementitious content, strength requirements) and can provide a path forward for reduced-carbon paving materials. There are several examples of state DOTs that have reduced the minimum cementitious content requirements in their specifications (Michigan, Pennsylvania), while other states have eliminated the minimum cementitious content requirements (Colorado, Iowa). A recent Rocky Mountain Institute (RMI) report (RMI 2024) highlights the potential for significantly reducing carbon emissions in concrete production by further revising state DOT concrete specifications. Overly prescriptive specifications often limit the use of lower-carbon mixtures and materials and limit opportunities for innovation. By removing minimum cement content requirements and expanding maximum SCM replacement percentages, DOTs can achieve substantial GHG emissions reductions.

However, improved and less prescriptive specifications do not always translate to contractors producing concrete mixtures with reduced cementitious contents. This document presents available (historical) data on trends in total cementitious content in DOT paving mixtures and explores the assertion that the industry has made significant progress over the past few decades in reducing the total cementitious content of their concrete paving mixtures.

# Data Review

## Long-Term Pavement Performance Program

The Long-Term Pavement Performance (LTPP) Strategic Study of Structural Factors for Rigid Pavements (SPS-2) experimental database was used as a benchmark because of the significant amount of detailed concrete mixture design data available for concrete pavements constructed during the 1990s. The states of Arizona, North Carolina, and Michigan were selected because they had state-specific concrete mixtures included in the LTPP SPS-2 experimental database. Additional mixture data were obtained directly from the DOTs or available reports from the National Concrete Pavement Technology Center (CP Tech Center) at Iowa State University. Table 1 provides a snapshot of the quantities of cement and total cementitious materials used between 1992 and 2023 (single mixtures) from the LTPP SPS-2 dataset.

Based on these data points, contractors in North Carolina and Arizona appear to have increased total cementitious materials content since the LTPP SPS-2 sections were constructed in the early 1990s, while contractors in Michigan appear to have initially reduced and more recently increased cementitious materials content. These data are from single mixtures used for these SPS-2 sections. Given the lack of additional relevant data, it was not possible to establish whether these mixtures are representative of the mixtures used in these states overall.

**Table 1. Examples of cementitious materials in concrete pavement mixtures (1992 to 2023, single mixtures)**

| State | Year | Cement (lb/yd³) | SCM (lb/yd³) | Total Cementitious Content (lb/yd³) |
|---|---|---|---|---|
| Arizona | 1993[1] | 400 | 100 | 500 |
| | 2008 | 423 | 141 | 564 |
| | 2013 | 451 | 113 | 564 |
| | 2023 | 489 | 122 | 611 |
| | 2023 | 500 | 88 | 588 |
| Michigan | 1993[1] | 451 | 113 | 564 |
| | 2006 | 329 | 141 | 470 |
| | 2020 | 394 | 132 | 526 |
| North Carolina | 1992[1] | 421 | 126 | 547 |
| | 2006 | 421 | 126 | 547 |
| | 2011 | 465 | 140 | 605 |
| | 2018 | 480 | 144 | 624 |
| | 2019 | 480 | 138 | 618 |

*[1] Mixture information from the LTPP SPS-2 database*

## State Outreach and Specification Review

Representatives (including DOT personnel and local concrete paving association staff) from seven different states that regularly construct concrete pavement (California, Colorado, Iowa, Minnesota, Texas, Pennsylvania, and Wisconsin) were contacted to gather information regarding trends in the cementitious materials content of their paving mixtures. Table 2 presents the Iowa DOT's trends in total cementitious content between 1923 and 2023 (multiple mixtures). When analyzed, the following trends emerge:

- Significant reduction in the portland cement content of concrete paving mixtures over the past 100 years, with the biggest reduction prior to 1995 (-186 lb/yd³).
- Slight increase in the portland cement content of concrete paving mixtures between the 1984 to 1994 and 1995 to 2000 periods (+28 lb/yd³) while the total cementitious content remained the same.
- Reduction in the portland cement content of concrete paving mixtures (-37 lb/yd³) between the 1995 to 2000 and 2000 to 2023 periods, with a slight reduction in total cementitious materials (-11 lb/yd³).

**Table 2. Average cementitious materials content in Iowa DOT concrete pavement mixtures (1923 to 2023) (data from Iowa DOT, number of concrete mixtures not provided)**

| Years | Cement Type | Cement (lb/yd³) | Fly Ash (lb/yd³) | Total Cementitious Content (lb/yd³) |
|---|---|---|---|---|
| 1923 to 1955 | — | 643 | — | 643 |
| 1956 to 1973 | — | 624 | — | 624 |
| 1974 to 1983 | — | 571 | — | 571 |
| 1984 to 1994 | — | 457 | 114 | 571 |
| 1995 to 2000 | I/II | 485 | 86 | 571 |
| 2000 to 2023 | I/II | 448 | 112 | 560 |

The California DOT (Caltrans) and Texas DOT (TxDOT) responded that records of actual portland cement usage over time are not readily available. They provided changes in specification criteria (e.g., minimum cementitious content), as did the Colorado/Wyoming (CO/WY) Chapter of the American Concrete Pavement Association (ACPA) for Colorado paving mixtures. Based on information provided by the CO/WY Chapter of ACPA, Colorado reduced the minimum allowable total cementitious content specification limit from 678 lb/yd³ in the 1990s to 520 lb/yd³ in 2017 and completely removed the limit in 2021. It is not clear, however, whether contractors took advantage of the lower limit other than anecdotally, knowing that some contractors use well-graded aggregate combinations that facilitate the reduction in total cementitious content while maintaining workability. Although lowering the minimum total cementitious materials content in the specification is a positive step toward allowing reduced-carbon mixtures, it is unknown how this impacted the total cementitious materials content in actual mixtures.

The Minnesota DOT (MnDOT) did not have detailed records of cementitious content over time. It pays incentives based on lowering the w/cm ratio, which it believes does not result in reduced cementitious content. As a result, MnDOT has maintained 570 to 600 lb/yd³ of total cementitious materials for decades but has increased fly ash content from 15% to 33% over time. While the total cementitious content may not be lower, the increase in fly ash suggests that the amount of portland cement in the mixtures has been reduced.

The Pennsylvania DOT (PennDOT) specifications showed no change in total cementitious content specification limits from 2000 to 2021. In 2021, the total cementitious content specification limit was reduced. In 2019, the minimum allowable cementitious content per specification for the standard pavement mixture was 587.5 lb/yd³ and the maximum was 752 lb/yd³. In 2021, for both long-life and standard pavement mixtures, the minimum and maximum changed to 517 lb/yd³ and 611 lb/yd³, respectively. Additionally, in 2021, Pennsylvania began requiring the use of well-graded aggregate combinations. Actual mixture proportion data were not provided, but the revised maximum limit on cementitious content is only 23.5 lb/yd³ more than the previous minimum limit. This, combined with the well-graded aggregate combination requirement, suggests that PennDOT is currently using concrete mixtures with lower cementitious contents than prior to 2021.

The Wisconsin DOT (WisDOT) specifications recently added language on well-graded aggregate combinations, as well as a wider range of allowable SCMs. Prior to 2022, well-graded aggregate combinations were not included in the specification; SCM usage was limited to fly ash, slag, and pozzolans; and the allowable SCM content was capped at 30% unless slipform paving was used, which allowed for up to 50% slag cement. Interestingly, the 2022 and 2023 specifications do not include a higher allowable SCM content for slipform paving applications, as was the case in previous years. The minimum cementitious content has remained consistent at 565 lb/yd³ for the past 20 years. However, this value increases to 660 lb/yd³ (2018 and 2021 specifications) if Type I, IL, or III cement is used and the coarse aggregate is primarily igneous or metamorphic. From 2022 onwards, if a well-graded aggregate combination is used, the minimum cementitious content is specified at 500 lb/yd³. Table 3 tracks the specification changes since 2003.

**Table 3. WisDOT specifications for concrete pavement mixtures (2003 to 2023)**

| Year | Minimum Total Cementitious Content (lb/yd³) | Optimized Aggregate Gradation? | Allowable SCM Content | SCMs Mentioned |
|---|---|---|---|---|
| 2003 | 565 | No | 30%[3] | fly ash, slag, pozzolans |
| 2008 | 565 | No | 30%[3] | fly ash, slag, pozzolans |
| 2013 | 565 | No | 30%[3] | fly ash, slag, pozzolans |
| 2018 | 565[1] | No | 30%[3] | fly ash, slag, pozzolans |
| 2021 | 565[1] | No | 30%[3] | fly ash, slag, pozzolans |
| 2022 | 565[2] | Yes | 15% to 30% | fly ash, slag, silica fume, blended SCMs, ASCMs |
| 2023 | 565[2] | Yes | 15% to 30% | fly ash, slag, silica fume, blended SCMs, ASCMs |

*[1] Minimum is 660 lb/yd³ if using Type I, IL, or III where coarse aggregate is primarily igneous or metamorphic*

*[2] Minimum is 500 lb/yd³ if optimized gradation is used*

*[3] Unless placing slipform paving, then up to 50% slag*

## FWHA Mobile Concrete Technology Center

Table 4 summarizes data on the cementitious content of concrete pavement from the FHWA Mobile Concrete Technology Center (MCTC) (previously the FHWA Mobile Concrete Laboratory) from the early 2000s (provided by Leif Wathne). These data are from concrete paving projects visited by the FHWA MCTC. Figure 1 presents these data graphically.

The total cementitious content ranged from 547 to 657.4 lb/yd³ with an average of 580.3 lb/yd³ (coefficient of variation [CV] = 5.9%). One mixture from California exceeded 650 lb/yd³. Excluding this mixture, the range shifted from 547 to 610 lb/yd³ with an average of 570.7 lb/yd³ (CV = 3.4%).

FHWA's MCTC provided additional mixture proportion data for projects across the country (2011 to 2022) (provided by Jagan Gudimettla). These data are summarized in Table 5 and Figure 2.

**Table 4. Data from MCTC (1999 to 2004)**

| State | Year | Location | Total Cementitious Content (lb/yd³) | Cement (lb/yd³) | Fly Ash (lb/yd³) | Slag (lb/yd³) |
|---|---|---|---|---|---|---|
| ND | 1999 | I-94 | 566.7 | 467.5 | 99.2 | 0 |
| NE | 2000 | US 275 | 561 | 510 | 51 | 0 |
| WI | 2002 | I-90 | 565 | 424 | 141 | 0 |
| NC | 2002 | I-26 | 610 | 469 | 141 | 0 |
| CA | 2002 | I-40 | 657.4 | 492.2 | 165.2 | 0 |
| NC | 2003 | Bonded OL | 547 | 421 | 126 | 0 |
| OK | 2004 | I-40 | 564 | 452 | 112 | 0 |
| DE | 2004 | Dover Toll Plaza | 564 | 282 | 0 | 282 |
| PA | 2004 | SR 22 - test section | 588 | 382 | 0 | 206 |

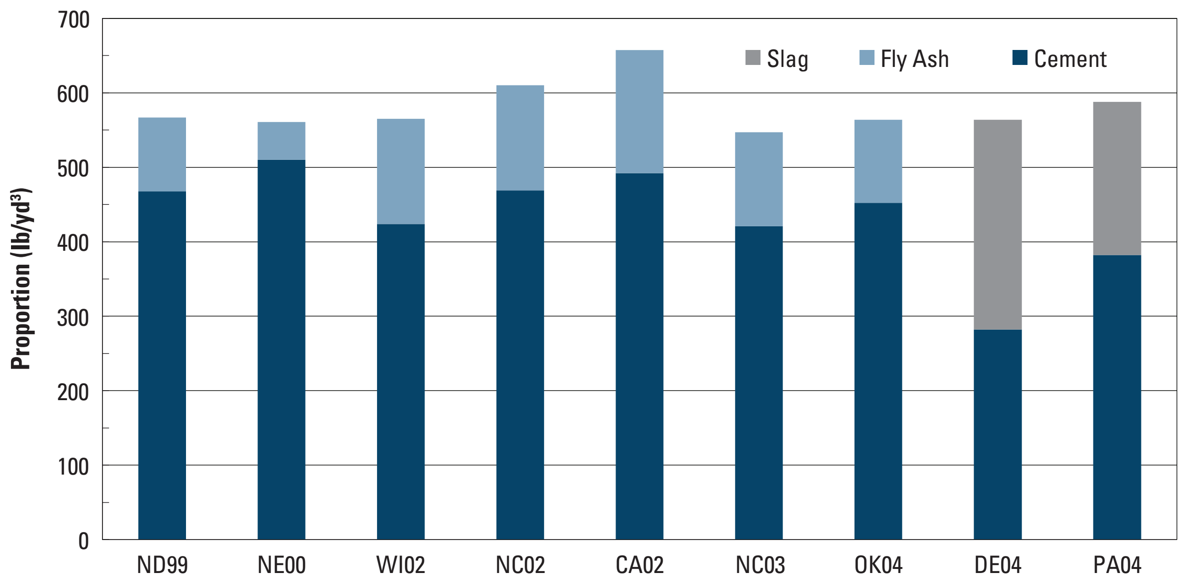


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**Figure 1. MCTC cementitious proportion data from projects visited around the country (1999 to 2004, with the year indicated by the two digits after the state abbreviation)**

**Table 5. MCTC mixture proportion data from projects visited around the country (2011 to 2022)**

| Project ID State/Year | Project | Year | Total CM[1] | % of SCMs | Cement (lb/yd³) | Fly Ash (lb/yd³) | Slag or other[2] | Max Agg. Size[3] | w/cm |
|---|---|---|---|---|---|---|---|---|---|
| NC11 | I-540 | 2011 | 605 | 23% | 465 | 140 | — | 1" | 0.41 |
| CA11 | I-80 | 2011 | 675 | 33% | 452 | 54 (F) | 169 | 2" | 0.37 |
| NV12 | I-80 | 2012 | 705 | 20% | 564 | — | 141(N)* | 2" | 0.37 |
| VA12 | RTE 58 | 2012 | 596 | 25% | 447 | 140 (F) | — | 1" | 0..43 |
| IA12 | US 71 | 2012 | 561 | 20% | 449 | 105 (C) | — | 1" | 0.40 |
| PA13 | US 202 | 2013 | 635 | 15% | 540 | 95 (F) | — | 1" | 0.41 |
| AZ13 | L303 | 2013 | 564 | 20% | 451 | 113 (F) | — | 2" | 0.44 |
| IL13 | I-90 | 2013 | 620 | 25% | 465 | 155 (C) | — | 1" | 0.42 |
| MI13 | US10 | 2013 | 500 | 25% | 375 | — | 125 (GG) | 2" | 0.42 |
| FL14 | I-4 | 2014 | 500 | 30% | 350 | 150 (F) | — | 1" | 0.45 |
| ID15 | I 90 | 2015 | 688 | 20% | 550 | 138 (F) | — | 1½" | 0.38 |
| OH15 | I-75 | 2015 | 555 | 25% | 417 | — | 138 (GG) | ¾" | 0.43 |
| WV13 | Corridor H | 2015 | 543 | 14% | 470 | 73 (?) | — | ¾" | 0.44 |
| NM15 | Mabry DR | 2015 | 564 | 30% | 395 | — | 169 (GG) | 1½" | 0.44 |
| WI16 | US 64 | 2016 | 565 | 30% | 395 | 170 (C) | — | 2" | 0.37 |
| SD16 | I 29 | 2016 | 605 | 20% | 484 | 121 (F) | — | 1½" | 0.40 |
| WA16 | I-90 | 2016 | 564 | 30% | 395 | — | 169 (GG) | 1½" | 0.44 |
| AR17 | I-440 | 2017 | 564 | 15% | 480 | 85 (C) | — | ¾" | 0.34 |
| DE17 | US 301 | 2017 | 564 | 50% | 282 | — | 282 (GG) | 1½" | 0.43 |
| CO18 | C-470 | 2018 | 550 | 20% | 440 | 110 (F) | — | 2" | 0.40 |
| IA18 | US-20 | 2018 | 565 | 20% | 449 | 112 (C) | — | — | 0.40 |
| MN18 | I-35 | 2018 | 560 | 30% | 390 | 170 (C) | — | — | 0.35 |
| NC19 | I-85 | 2019 | 605 | 23% | 465 | 140 (C) | — | — | 0.41 |
| CA19-1 | I-5 | 2019 | 510 | 15% | 433 | 77 (F) | — | — | 0.49 |
| CA19-2 | RTE 58 | 2019 | 530 | 16% | 445 | 85 (F) | — | — | 0.48 |
| KS-19 | I-70 | 2019 | 540 | 25% | 405 | 135 (C) | — | — | 0.42 |
| FL21 | US-301 | 2021 | 470 | 20% | 376 | 94 (F) | — | — | 0.50 |
| WY22 | I-80 E | 2022 | 587.5 | 20% | 470 | 117 (F) | — | — | 0.41 |
| ND22 | US-2 E | 2022 | 551 | 29% | 391 | 160 (F) | — | — | 0.40 |
| SC22 | I-26 | 2022 | 600 | 20% | 480 | 120 (F) | — | — | 0.42 |

*[1] Total cementitious materials content (lb/yd³)*

*[2] Slag or other pozzolan (lb/yd³)*

*[3] Maximum size of aggregate (in.)*

** Natural pozzolan*

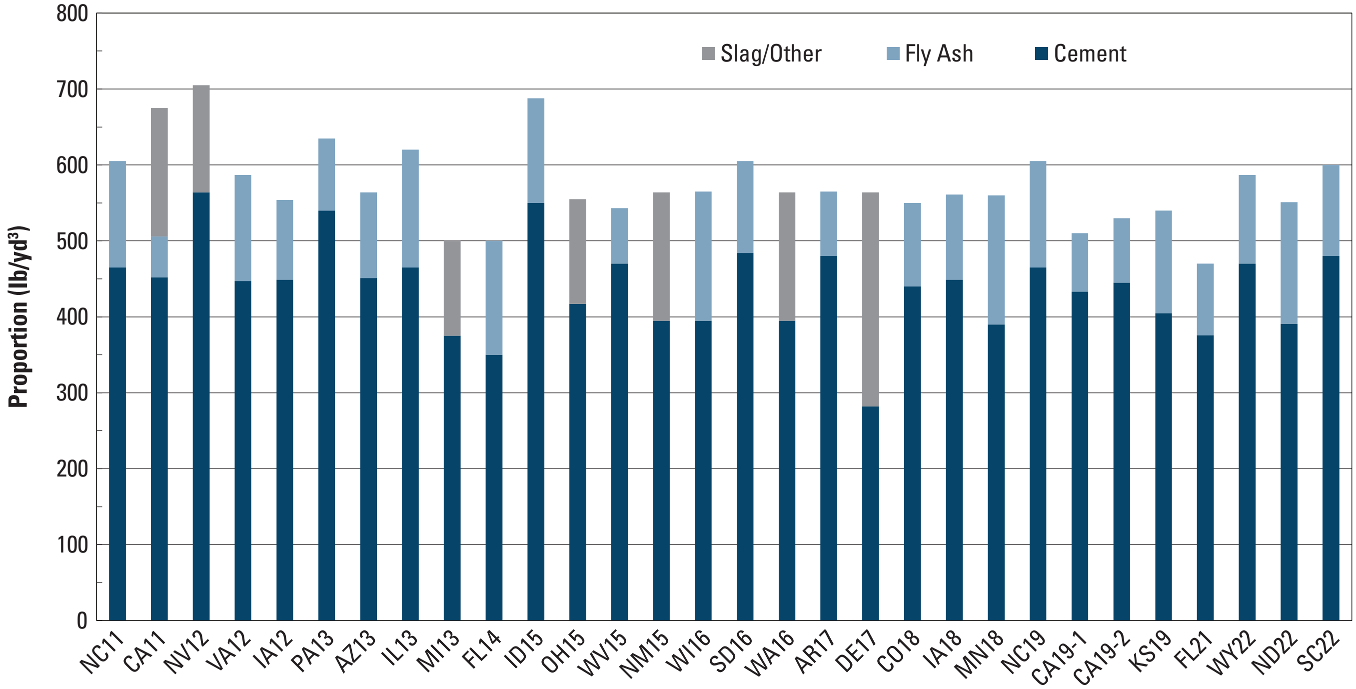


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**Figure 2. MCTC cementitious proportion data from projects visited around the country (2011 to 2022, with the year indicated by the two digits after the state abbreviation)**

The total cementitious content ranged from 470 to 705 lb/yd³ with an average of 573.7 lb/yd³ (CV = 9.4%). The three mixtures with more than 650 lb/yd³ total cementitious content were placed in California, Nevada, and Idaho. Excluding these three mixtures, the range shifted from 470 to 635 lb/yd³ with an average of 560.3 lb/yd³ (CV = 9.4%).

A comparison was made using previously presented mixture data for Arizona, Delaware, Michigan, North Carolina, Pennsylvania, and Wisconsin (Table 6). To be considered for the comparison, the state needed to have at least two mix designs (to compare over time) and had to have historical DOT specifications available online. These mixture designs were compared to their corresponding state specifications to demonstrate what actual mixture proportions were being used versus what the specification allowed regarding cementitious content (at that time). These data represent single mixture designs.

Observations from the data in Table 6 include the following:

- The total cementitious content either stayed the same or increased over the past two decades, even though the specified minimum allowable cementitious materials criteria remained the same for each state.
- The specified minimum cementitious content in Arizona, Delaware, Pennsylvania, and Wisconsin may have been a limiting factor because many actual mixtures had total cementitious materials contents at or just above the specified minimum.
- States allowed varying percentages of SCMs, but a noticeable increase in allowable SCMs was not observed, except for Michigan. In the 2020 specifications, Michigan required that 25% to 40% of portland cement be replaced with SCMs.

**Table 6. Comparison between MCTC mixture design data and applicable specification**

| State | Project Year | Specification Year | Minimum Allowable Cementitious Content ($lb/yd^3$) | Total Cementitious Content ($lb/yd^3$) | Cement ($lb/yd^3$) | SCM ($lb/yd^3$) | SCM % | SCM Type | Maximum Allowable SCM % |
|---|---|---|---|---|---|---|---|---|---|
| AZ | 2008 | 2008 | 564 | 564 | 423 | 141 | 25% | N/A | 25% |
| | 2013 | 2008 | 564 | 564 | 451 | 113 | 20% | N/A | 25% |
| | 2023 | 2021 | 564 | 611 | 489 | 122 | 20% | N/A | 25% |
| | 2023 | 2021 | 564 | 588 | 500 | 88 | 15% | N/A | 25% |
| DE | 2004 | 2001 | 564 | 564 | 282 | 282 | 50% | Slag | 50% |
| | 2017 | 2016 | — | 564 | 282 | 282 | 50% | Slag | N/A |
| MI | 2013 | 2012 | 470 | 500 | 375 | 125 | 25% | Slag | 20% FA, slag not mentioned |
| | 2020 | 2020 | 470 | 526 | 394 | 132 | 25% | N/A | 40% |
| NC | 2002 | 2002 | 526 | 610 | 469 | 141 | 23% | Pozzolan | 20% FA, 50% slag |
| | 2011 | 2006 | 526 | 605 | 465 | 140 | 23% | Pozzolan | 20% FA, 50% slag |
| | 2019 | 2018 | 526 | 605 | 465 | 140 | 23% | FA | 20% FA, 50% slag |
| PA | 2004 | 2003 | 587.5 | 588 | 382 | 206 | 35% | Slag | 50% max slag |
| | 2013 | 2011 | 587.5 | 635 | 540 | 95 | 15% | FA | 25% max FA |
| WI | 2003 | 2001 | 565 | 565 | 424 | 141 | 25% | FA | 30% FA |
| | 2016 | 2013 | 565 | 565 | 395 | 170 | 30% | FA | 30% FA |

*FA = fly ash*

# Summary

This document presents available (historical) data on trends in total cementitious content in DOT paving mixtures and explores the hypothesis that the industry has made progress over the past few decades in reducing total cementitious content, thus reducing GHG emissions. Available data from the LTPP database, select state DOTs, FHWA's MCTC, and the CP Tech Center at Iowa State University were compiled and reviewed. Data to support the claim that cement intensity has decreased over time are limited and, at times, conflicting. The available data suggest that portland cement content has remained the same or possibly even increased in concrete paving mixtures over the last few decades. Some key observations include the following:

- The state DOTs contacted for this analysis do not keep detailed concrete mixture proportion records over time and specifically do not retain records related to total cementitious and portland cement contents. Some agencies had information on general trends in cementitious content over the years.
- The data reviewed do not support the claim that reduced-carbon concrete mixtures are routinely being placed by contractors, even when agencies permit lower total cementitious content in their specifications. In fact, one state reported that the total amount of cementitious content has increased in recent years.
- The FHWA MCTC data reported 9 mixtures from 1999 to 2004 with an average total cementitious content of 580.3 lb/yd$^3$ and 30 mixtures from 2011 to 2022 with an average total cementitious content of 573.7 lb/yd$^3$, representing a minimal reduction in total cementitious content between the early 2000s and 2010s/early 2020s.

It appears that some DOT specifications may remain a barrier to constructing with reduced-carbon concrete mixtures. It also does not appear that contractors are taking full advantage of the cement reductions allowed by some DOT specifications. The latter could be related to minimum strength requirements embedded within the specifications for opening a paving lane to construction traffic or other construction activities (e.g., drilling in tie/dowel bars) or simply to the fact that additional cementitious materials are being used to reduce the monetary risk associated with not meeting strength requirements.

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