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Overview of ACI 323 Low Carbon Concrete Code

January 30th, 2025

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AGENDA

- Motivation for ACI Low-Carbon Concrete Code
- Code Development Process and Timeline
- ACI CODE-323 Overview
- Project Example
- What's Next for Industry?
- Q&A

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MOTIVATION FOR CODE & TAC GUIDANCE

- Other organizations have taken action to date without input from ACI
  - Marin County, California
  - ASHRAE
  - CLF,NRDC,NBI,RMI, etc.
  - CalGreen
  - Federal agencies (GSA, EPA, FHWA)

- Inconsistent policy action and ambiguity around term “low-carbon”
- ACI authorized code development in 2023 to take leadership role
  - Aggressive 1-year goal for first edition of code
  - Committee recruited in early 2023
- TAC Guidance on meaning of “low-carbon”

ACI 323 COMMITTEE

DRAFT: Do Not Circulate or Publish

Low-Carbon Concrete – Code Requirements and Commentary

An ACI Standard

Reported by ACI Committee 323

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Photo courtesy Matthew Adams

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CODE DEVELOPMENT PROCESS AND TIMELINE

- April 2023 – First committee meeting at spring convention in San Francisco
- July 2023 – Full-day workshop at ACI HQ
  - Reviewed first draft of code
  - Consensus on concept of “low-carbon” as 85% of NRMCA or local benchmark
- August 2023 – First ballot of complete code and commentary
- October 2023 – Committee approved code at Boston convention, submitted to TAC
- January 2024 – TAC comments sent to committee
- February-March 2024 – TAC comments addressed
- March 31, 2024 – May 15, 2024 Public Comment
- October 2024 – Published

KEY TENETS

- Scope, Purpose, and Exceptions
- Primacy of Life Safety, Durability, Serviceability [LDP flexibility]
- Project Size Tiers and Types
- No Prescription of Mix Designs
- Carbon Budget Approach (No requirement for individual mix-by-mix compliance)
- Consideration of Regionality [8 NRMCA regions or local benchmark setting]
  - NRMCA targeting 30 regions/major metros in next benchmark report (~2025) and more product categories.
  - 50 regions/metros by ~2029-30 | indoor vs. outdoor mixes.

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CONSTRAINTS AND LIMITATIONS

- Timeframe: ACI set goal of completion within the year 2024
- Codes are mandatory language documents
- Data we have now versus data we want
  - Impacts scope and exclusions in the code
  - More EPDs will help some
  - PCR revisions also needed

CODE OVERVIEW

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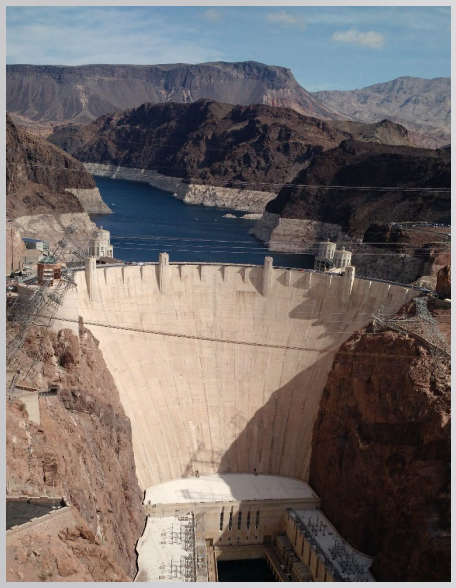

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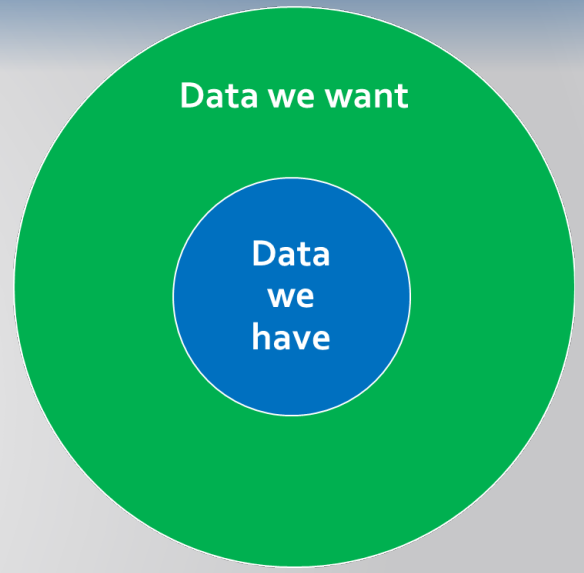
KEY PROVISIONS: CHAPTER 1 (GENERAL)

- **Purpose:** Provide requirements for limiting GWP of concrete on a project. Can be applied to new construction, as well as repairs/alterations/additions. [1.3.1]
- **Scope and Applicability**
  - "The provisions of this Code shall be in addition to those of the governing building or structural design code, standard, rule, or regulation." [1.1.2]
  - Cast-in-place concrete with specified compressive strength (f'_c) 2501 – 8000 psi. [1.4.3] (Limited by currently available NRMCA benchmark data)
  - "The licensed design professional shall be permitted to specify more stringent requirements than those provided in this Code." [1.4.5]

KEY EXCLUSIONS: CHAPTER 1 (GENERAL)

Code **does not apply** to:

- Concrete with $f'_c > 8000$ psi
- Concrete with $f'_c \leq 2500$ psi
- Precast concrete
- Auger cast concrete
- Shotcrete



Other **significant exceptions** (LDP and AHJ discretion):

- "This code… is not intended for use where compliance will compromise the required strength, stability, serviceability, durability, or integrity of the concrete structure." [1.3.3]
- "GWP requirements of this Code shall be limited or excluded if the authority having jurisdiction or entity adopting this Code determines the requirements in Chapters 5 through 8 are not feasible." [1.4.4]

EPDs AND RELATED TERMINOLOGY

- Environmental product declaration (EPD)
- Product category rule (PCR)
- Life cycle assessment (LCA)

- Global warming potential (GWP) – the combined effect of all greenhouse gas emissions, expressed as *CO_2-equivalent*.
- Embodied carbon (EC), a.k.a. “carbon footprint” – GWP associated with a product’s life cycle. “Upfront” or “cradle-to-gate” EC is associated with manufacturing stages
- There are different PCRs and EPDs for cement, ready mix concrete, and concrete masonry products

KEY PROVISIONS: CHAPTER 4

- GWP requirements apply to concrete mixture materials (including fibers)
- Only "**upfront embodied**" GWP considered at this time (A1 to A3 LCA modules)
- LDP **specifies** appropriate GWP requirements for the project based on structure types in Chapters 5 through 8 and **verifies documentation** for the project.
- Acceptable documentation of GWP
  - Independent, third-party verified
  - Product-specific EPD, LCA report, or LCA tool output
- **Carbon budget** (weighted average) approach for project → **flexibility**
- Consideration of **regionality** – GWP benchmarks by **strength class*** are set by adopting jurisdiction or entity. May use NRMCA regional benchmarks (Appendix A).

  * Specified strength does not have to be at 28 days → **flexibility**

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CARBON BUDGET APPROACH

CODE
4.4.1 The weighted average project GWP shall be calculated using Equation 4.4.1. $$GWP_{project\ avg} = \frac{\sum_{i=1}^{n} GWP_{project\ i} \times Vol_i}{\sum_{i=1}^{n} Vol_i} \quad (4.4.1)$$
4.4.1.1 The individual GWP values used in Equation 4.4.1 shall meet the requirements of 4.3.
4.4.2 The weighted average benchmark GWP shall be provided as a weighted average of the classes of the total volume of concrete on the project using Equation 4.4.2. $$GWP_{benchmark\ avg} = \frac{\sum_{i=1}^{n} GWP_{benchmark\ i} \times Vol_i}{\sum_{i=1}^{n} Vol_i} \quad (4.4.2)$$

Calculate the average GWP of your project, weighted by volume used.

Calculate the average GWP benchmark for your project across all, weighted by volume used.

Content courtesy Matthew Adams

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KEY PROVISIONS: PROJECT TYPES AND TIERS

Project Size	Chapter 5 Buildings (Gross Floor Area)		Chapter 6 Pavements and Hardscapes (Volume)		Chapter 7 Bridges (Deck Area)		Chapter 8 Other Structures (Volume)	
Tier 1	BL1	≥ 50,000 ft^2	PH1	≥ 7,500 yd^3	BR1	≥ 25,000 ft^2	S1	≥ 7,500 yd^3
Tier 2	BL2	< 50,000 ft^2 ≥ 5,000 ft^2	PH2	< 7,500 yd^3 ≥ 2,000 yd^3	BR2	< 25,000 ft^2 ≥ 5,000 ft^2	S2	< 7,500 yd^3 ≥ 2,000 yd^3
Tier 3	BL3	< 5,000 ft^2	PH3	< 2,000 yd^3	BR3	< 5,000 ft^2	S3	< 2,000 yd^3

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KEY PROVISIONS: COMPLIANCE

- Structure of Chapters 5 through 8 is similar.
- Separate chapters facilitate use of different benchmarks for each project type.
- α = GWP reduction factor.
  Set by adopting entity. Shall be 0.85 when using NRMCA regional benchmarks.

Project Size	GWP Limit	Compliance Documentation
Tier 1	$GWP_{project\ avg} \leq \alpha\ GWP_{benchmark\ avg}$	5.3.2, 5.3.3
Tier 2	None	5.3.2, 5.3.3
Tier 3	None	5.3.3

5.3.2 Documentation for building projects shall report the following:
(a) ($GWP_{project\ avg}$/ $GWP_{benchmark\ avg}$),
(b) $GWP_{project\ avg}$
(c) $GWP_{benchmark\ avg}$, and
(d) $GWP_{benchmark\ i}$, $GWP_{project\ i}$, and Vol_i for every class of concrete on the project.

5.3.3 Building projects shall document all concrete mixtures used on the project with their corresponding use, specified compressive strength, exposure categories and any other performance requirements, and a summary of any strategies used to reduce the GWP of the concrete on the project.

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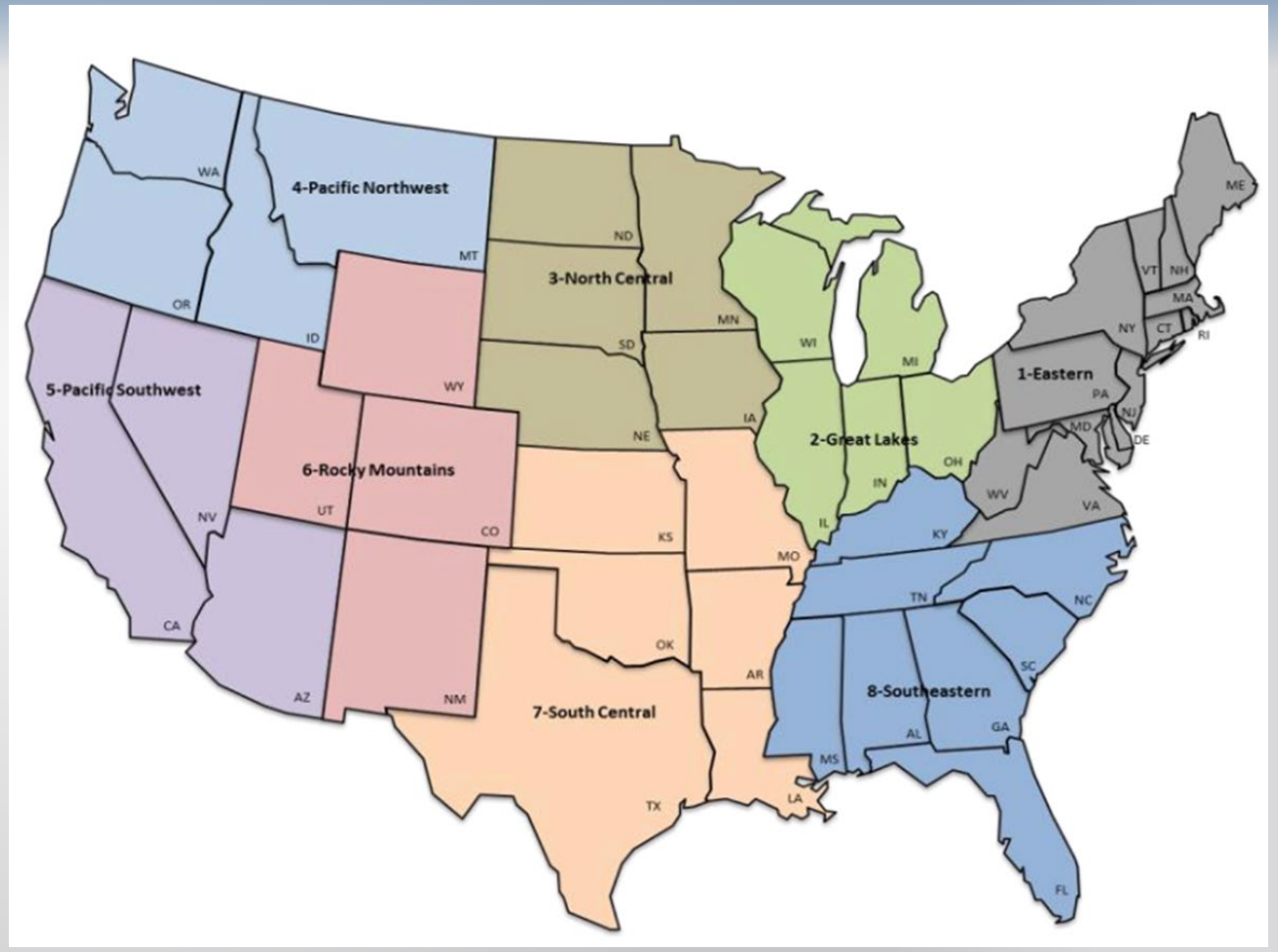
APPENDIX A: NRMCA REGIONAL BENCHMARKS

- **2022 benchmark report (V3.2)**
  - 8 regions
  - Benchmarks for:
    2501 – 3000 psi (Normal- and lightweight)
    3001 – 4000 psi (Normal- and lightweight)
    4001 – 5000 psi (Normal- and lightweight)
    5001 – 6000 psi (Normalweight only)
    6001 – 8000 psi (Normalweight only)
- Use is permitted, but **preference** for adopting entity to set own benchmarks based on statistical analysis of local/regional data.
- Use is limited to projects in contiguous U.S. (lower 48).



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Project Example

PROJECT EXAMPLE

- Building project in California (Pacific Southwest Region)
  - Size > 50,000 ft^2 → Tier BL1 (full compliance & documentation required)
  - No local GWP benchmarks established
    → Use NRMCA Pacific Southwest Region with α = 0.85

Table A.3.1(e) Region 5 (Pacific Southwest) GWP benchmark values by strength.

Strength (f'_c) at 28 days (psi)	Normalweight Concrete $GWP_{benchmark\ i}$ *(kg CO_2e / yd^3 concrete)*	Lightweight Concrete $GWP_{benchmark\ i}$ *(kg CO_2e / yd^3 concrete)*
2501 to 3000	214	383
3001 to 4000	248	418
4001 to 5000	289	454
5001 to 6000	307	Not Applicable
6001 to 8000	349	Not Applicable

MIXTURE TYPES, QUANTITIES, AND CHARACTERISTICS

CONC MIX TYPE	INTENDED USE	QUANTITY (CY)	EXPOSURE CATEGORIES AND CLASSES	STRENGTH, f'c (KSI)	TEST AVG (DAYS)	CONC. WEIGHT	MAX W/C RATIO	MAX AGG. SIZE (IN)	TOTAL AIR CONTENT (%)
1A	DRILLED PIERS	450	F0, S1, W1, C1	3.00	56	NWC	--	1	--
1B	FOOTINGS	350	F0, S1, W1, C1	3.00	28	NWC	--	1	--
1C	HOLLOW SHELL PILES	150	F0, S0, W0, C0	3.00	56	NWC	--	3/4	--
2A	INTERIOR PIER CAPS, GRADE AND TIE BEAMS	200	F0, S0, W1, C1	3.00	56	LWC	--	3/4	--
2B	EXTERIOR PIER CAPS, GRADE AND TIE BEAMS	250	F1, S1, W1, C1	3.50	56	NWC	0.55	3/4	5
2C	EXTERIOR PIER CAPS, GRADE AND TIE BEAMS EXPOSED TO MOISTURE	350	F1, S1, W1, C0	3.50	56	NWC	0.50	3/4	5
3A	BASEMENT AND RETAINING WALLS	350	F1, S1, W1, C1	3.50	28	NWC	0.55	3/4	5
3B	BASEMENT AND RETAINING WALLS EXPOSED TO MOISTURE	250	F1, S1, W1, C1	3.50	28	NWC	0.50	3/4	5
4A	INTERIOR SLABS-ON-GRADE	650	F0, S0, W0, C0	4.50	28	NWC	--	1	3
4B	INTERIOR SUSPENDED SLABS	175	F0, S0, W0, C0	4.50	28	LWC	--	3/4	3
4C	INTERIOR INDUSTRIAL SLABS-ON-GRADE	1100	F0, S0, W0, C0	4.50	28	NWC	--	1	3

GWP – FROM READY MIX SUPPLIER

CONC MIX TYPE	INTENDED USE	QUANTITY (CY)	MIX DESIGN GWP (FROM EPDs: (kg CO_2e/YD_3))
1A	DRILLED PIERS	450	175
1B	FOOTINGS	350	175
1C	HOLLOW SHELL PILES	150	175
2A	INTERIOR PIER CAPS, GRADE AND TIE BEAMS	200	325
2B	EXTERIOR PIER CAPS, GRADE AND TIE BEAMS	250	200
2C	EXTERIOR PIER CAPS, GRADE AND TIE BEAMS EXPOSED TO MOISTURE	350	200
3A	BASEMENT AND RETAINING WALLS	350	200
3B	BASEMENT AND RETAINING WALLS EXPOSED TO MOISTURE	250	200
4A	INTERIOR SLABS-ON-GRADE	650	280
4B	INTERIOR SUSPENDED SLABS	175	450
4C	INTERIOR INDUSTRIAL SLABS-ON-GRADE	1100	205

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COMPARISON OF PROPOSED AND ALLOWED GWP

CONC MIX TYPE	INTENDED USE	QUANTITY (CY)	MIX DESIGN GWP (FROM EPDs: (kg CO_2e/YD_3))	PAC. SW NRMCA REGIONAL AVERAGE GWP (kg CO_2e/YD_3)
1A	DRILLED PIERS	450	175	214
1B	FOOTINGS	350	175	214
1C	HOLLOW SHELL PILES	150	175	214
2A	INTERIOR PIER CAPS, GRADE AND TIE BEAMS	200	325	370
2B	EXTERIOR PIER CAPS, GRADE AND TIE BEAMS	250	200	248
2C	EXTERIOR PIER CAPS, GRADE AND TIE BEAMS EXPOSED TO MOISTURE	350	200	248
3A	BASEMENT AND RETAINING WALLS	350	200	248
3B	BASEMENT AND RETAINING WALLS EXPOSED TO MOISTURE	250	200	248
4A	INTERIOR SLABS-ON-GRADE	650	280	274
4B	INTERIOR SUSPENDED SLABS	175	450	444
4C	INTERIOR INDUSTRIAL SLABS-ON-GRADE	1100	205	274

COMPARISON OF PROPOSED AND ALLOWED GWP

CONC MIX TYPE	INTENDED USE	QUANTITY (CY)	MIX DESIGN GWP (FROM EPDs: (kg CO2e/YD3))	PAC. SW NRMCA REGIONAL AVERAGE GWP (kg CO2e/YD3)	ACI 323 GWP LIMIT (85% of NRMCA REGIONAL AVERAGE GWP) (kg CO2e/YD3)
1A	DRILLED PIERS	450	175	214	181.9
1B	FOOTINGS	350	175	214	181.9
1C	HOLLOW SHELL PILES	150	175	214	181.9
2A	INTERIOR PIER CAPS, GRADE AND TIE BEAMS	200	325	370	314.5
2B	EXTERIOR PIER CAPS, GRADE AND TIE BEAMS	250	200	248	210.8
2C	EXTERIOR PIER CAPS, GRADE AND TIE BEAMS EXPOSED TO MOISTURE	350	200	248	210.8
3A	BASEMENT AND RETAINING WALLS	350	200	248	210.8
3B	BASEMENT AND RETAINING WALLS EXPOSED TO MOISTURE	250	200	248	210.8
4A	INTERIOR SLABS-ON-GRADE	650	280	274	232.9
4B	INTERIOR SUSPENDED SLABS	175	450	444	377.4
4C	INTERIOR INDUSTRIAL SLABS-ON-GRADE	1100	205	274	232.9

COMPARISON OF PROPOSED AND ALLOWED GWP

CONC MIX TYPE	INTENDED USE	QUANTITY (CY)	MIX DESIGN GWP (FROM EPDs: (kg CO_2e/YD_3))	PAC. SW NRMCA REGIONAL AVERAGE GWP (kg CO_2e/YD_3)	ACI 323 GWP LIMIT (85% of NRMCA REGIONAL AVERAGE GWP) (kg CO_2e/YD_3)
1A	DRILLED PIERS	450	175	214	181.9
1B	FOOTINGS	350	175	214	181.9
1C	HOLLOW SHELL PILES	150	175	214	181.9
2A	INTERIOR PIER CAPS, GRADE AND TIE BEAMS	200	325	370	314.5
2B	EXTERIOR PIER CAPS, GRADE AND TIE BEAMS	250	200	248	210.8
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4A	INTERIOR SLABS-ON-GRADE	650	280	274	232.9
4B	INTERIOR SUSPENDED SLABS	175	450	444	377.4
4C	INTERIOR INDUSTRIAL SLABS-ON-GRADE	1100	205	274	232.9
			957,500 kg CO_2e		962,285 kg CO_2e
			TOTAL PROJECT GWP is less than:		ALLOWABLE PROJECT GWP

EXAMPLE SUMMARY

- $GWP_{benchmark\ avg}$ = 271.98 kg $CO_{2\text{-}eq}/yd^3$
- $GWP_{project\ avg}$= 224.44 kg $CO_{2\text{-}eq}/yd^3$
- $GWP_{project\ avg}$ / $GWP_{benchmark\ avg}$ = **0.825 < 0.85**
- 11 total mixes
  - 3 mixes exceeded 85% of benchmark (inc. 2 lightweight)
  - 5 mixes used 56-day strength instead of 28-day
- Project under 85% of total carbon budget → **complies!**

What's Next for Industry?

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HOW TO PREPARE

- Push for local benchmarking / participate!
- Begin process of getting EPDs!
- Watch for EPD funding support (PCA, NRMCA)

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OUTREACH AND ADOPTION

- ACI Code Advocacy
  - Potentially IgCC (ASHRAE 189.1), Others?
- NEU – Documentation Tool, Training, and Outreach
- Adoption “Toolkits” for Jurisdictions & Agencies
  - Alignment with decarbonization goals
  - Encourage use of local benchmarking

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Thank you!

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