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Abstract

The Carolina Crossroads project is a state infrastructure design-build project that will cost US$2.08 billion and span several years. It involves renovating 14 miles of I-20, I-26, and I-126, also known as "Malfunction Junction." This project is part of the South Carolina Department of Transportation's (SCDOT) 10-Year Plan, which consists of five phases. The first two phases are underway, and the entire corridor is expected to be completed in 2029.
This area sees more than 134,000 vehicles daily. Upon project completion, the average commuter through the I-20/26/126 corridor will save 112 hours each year.

Phase 1 of the project involves redesigning and constructing a new interchange for Colonial Life Boulevard at I-126 and improving I-26 and I-126. The semi-directional interchange concept is being used, which is safer and more efficient.

Phase 2 will update the Broad River Road interchange at I-20 to improve interstate traffic flow and lengthen I-20 westbound access to I-26 westbound to reduce congestion from vehicles changing interstates. To minimize the number of traffic stages and avoid closing existing ramps, an "off-alignment" construction scheme will be used. Given the high congestion level in this area, ensuring the maintenance of traffic during construction was a key focus of the JV's approach.

Phase 3 involves completing all work necessary to design and reconstruct new interchanges at I-20 with I-26, I-26 with I-126, St. Andrews Road (S-36) with I-26, and Bush River Road (S-273) with I-20. This includes widening the interstate, constructing interchange ramps, collector-distributor roads, crossing routes, frontage roads, side roads, highway bridges, riverine bridges, railroad bridges, retaining walls, noise barrier walls, and related roadway appurtenances in Richland and Lexington Counties.

This paper will only focus on Project ID P03971, which comprises the I-26 to I-20 FUTURE RAMPS, and the construction of the I-26 WB to I-126 EB bridge over the Saluda River and CSX R.R. It's the largest and most complex bridge on both Phases 1 and 2. This project involves numerous technical details that will be discussed in depth.

Galvanized rebar is now required for all new bridge decks and concrete structures like barriers and sidewalks in Phase 2 of the Carolina Crossroads Project. It was not part of the original RFP for Phase 1 but was later incorporated via a change order. ASTM A767 was referenced, but the JV proposed ASTM A1094 as a substitute due to its resistance to corrosion, low maintenance requirements, and streamlined logistics to provide an equal or better product, and SCDOT approved it.

The procurement portion played a key role in the approval of ASTM A1094, as the ability to have staged rebar ready for fabrication, respond to last-minute changes, and minimize lead times is a big deal on large projects. Also, the A1094 steel is rolled and galvanized at the Mill, the product comes directly from the Mill to the fabricators and can be fabricated like uncoated "black" rebar, which helps expedite deliveries.
Additionally, the availability of mill lengths beyond 60 feet /18+ meter significantly benefits longer bridge projects, reducing the number of splices required.

The Carolina Crossroads Project (CCR)

The South Carolina Department of Transportation (SCDOT) is implementing an innovative turbine design and collector/distributor ramps at the I-20/26 Interchange, providing a safer and more efficient way for drivers to transition between interstates. Turbine designs offer an alternative to conventional interstate on- and off-ramps. This four-way directional interchange design is gaining popularity among highway designers due to its ability to retain directional ramps while requiring fewer levels (typically two or three). Additionally, they feature right-exit, left-turning ramps that sweep around the center of an interchange in a clockwise spiral.

Phase 1 Key Project Details

Archer-United Joint Venture was awarded the Malfunction Junction construction project by SCDOT. The project began in 2021 and is expected to conclude in 2024. The engineer of record for the Carolina Crossroads project Phase 1 is Infrastructure Consulting & Engineering. The project's first phase focuses on the area between Colonial Life Blvd and US 378.

Phase 1 is comprised of two essential elements. The first is the construction of a new full-access interchange at Colonial Life Boulevard to replace the Bush River Road interchange at I-26. This change is intended to enhance traffic flow and safety by eliminating an adverse weave on I-26 westbound between I-20 and I-126.

The second component involves lengthening the I-26 eastbound exit ramp to US 378 / Sunset Boulevard. This modification is necessary to accommodate the high volume of vehicles that exit here in the afternoon and prevent stopped vehicles on the interstate shoulders.

This document will focus on Project ID P03971, which comprises the I-26 to I-20 FUTURE RAMPS and the construction of the I-26 WB to I-126 EB bridge over the Saluda River and CSX R.R. It’s the largest and most complex bridge structure on both Phases 1 and 2.

Figure 1. Carolina Crossroads Phase 1: I-26 to I-20 FUTURE RAMPS

Source: SCDOT

Phase 1 of the improvements on I-126 will begin in downtown Columbia and move towards the west. To access Colonial Life Boulevard, drivers will take the existing right exit ramp. Once at the top of the ramp, drivers will veer right to merge onto Colonial Life Boulevard and then continue onto the Bush River Road intersection. This will lead them back to the starting point of this route.

For drivers leaving downtown Columbia via I-126 westbound and traveling towards I-26 westbound, they will continue using the left two lanes as they currently do. If they are traveling to I-26 eastbound towards Charleston, they will follow the same route as they currently do. They will pass the Colonial Life Boulevard ramp and merge right onto the existing flyover bridge over I-126 and the Saluda River. Then, they will merge onto I-26 eastbound.

One of the most significant changes in Phase 1 is the construction of a diverging diamond interchange at Colonial Life Boulevard. This type of interchange may feel vastly different from a traditional one initially, but it is easy to drive through and is a safe and effective way to move a large volume of traffic through an interchange.

To reach I-126 from Bush River Road, drivers will need to navigate the diverging diamond interchange at Colonial Life Boulevard. To access I-126 eastbound towards downtown Columbia, drivers should move to the left-hand lane towards the signal at the diverging diamond interchange. They will cross through the interchange and proceed to the existing bridge from Colonial Life Boulevard, merging into I-126 westbound as they currently do.

During Phase 1 construction, the existing bridge will undergo rehabilitation. For drivers traveling from Bush River Road to I-26 eastbound or westbound, the route will be on the right side of the diverging diamond interchange on Colonial Life Boulevard. They will drive over a new bridge that passes over Arrowwood Road and a new I-126 ramp to I-26 east. Once they cross the new bridge, they will reach a split in the route. Drivers can veer left and merge onto I-26 West or go right to connect to the existing flyover ramp to I-26 East.

Drivers who are traveling from I-126 eastbound and need to access Bush River Road will now take a new exit ramp at Colonial Life Boulevard. They will then drive through the signal at the diverging diamond interchange and continue towards Bush River Road on I-26. Additionally, the eastbound exit ramp at US-378 will be lengthened to improve mainline functionality.

For drivers who need to access Bush River Road or travel into downtown Columbia from I-26, they will stay in the right lane and exit onto a new bridge that crosses over the Saluda River. The bridge will follow alongside the river, just south of the existing railroad tracks, before merging onto I-126. The ramp will then split, with a veer to the left taking drivers over I-126, running parallel with traffic coming from I-126 east towards the Colonial Life Boulevard diverging diamond interchange. The veer to the right will put travelers on a new ramp to merge with traffic on the existing I-126 east towards downtown Columbia.

The current Bush River Road interchange ramps at I-26 will be removed, and drivers will now access Bush River Road via the new diverging diamond interchange at Colonial Life Boulevard. This change will alleviate side swipes caused by drivers trying to merge onto I-26 eastbound from I-20 eastbound.

Major construction activities for Phase 1 started in the fall of 2021, and substantial completion is anticipated for late 2024.

Figure 2. I-26 WB to I-126 EB bridge over the Saluda River and CSX R.R.

Source: SCDOT scdotcarolinacrossroads.com

Design Criteria

Specifications are based on AASHTO LRFD Bridge Design Specifications, 8th Edition, with interim revisions.
Design data: live load AASHTO HL -93 Loading
Straddle Bent Cap Redundancy Load Modifier = 1.05
The top 6.35 mm of all concrete slabs is considered a wearing surface and is not included in the slab depth used to calculate section properties. All bolted connections, except steel diaphragm members used with prestressed concrete beams, are designed as slip-critical connections with Class B contact surfaces. To accommodate the use of steel stay-in-place forms, an extra dead load of 0.015 KSF is incorporated into the design of this structure.
Seismic design is in accordance with the 2008 SCDOT "Seismic Design Specifications for Highway Bridges" Version 2.0. Reinforcing steel is ASTM A-706 grade 60, low-alloy steel deformed rebar, and the corrosion-resistant reinforcing is ASTM A1094 with ASTM A706 base.

Figure 3. SCDOT "Seismic Design Specifications for Highway Bridges"

Seismic Design Category: B

Analysis Method: Multimode Spectral

Operational Classification: I

Design Acceleration Coefficients:

PGA	(FEE):	0.20 g
S_{DS}	(FEE):	0.36 g
S_{D1}	(FEE):	0.10 g
PGA	(SEE):	0.39 g
S_{DS}	(SEE):	0.82 g
S_{D1}	(SEE):	0.28 g

Source: Infrastructure Consulting & Engineering

All cast-in-place concrete bridge components are constructed with Class 4000 concrete, and all precast concrete bridge components use concrete with a minimum compressive strength of 5000 psi.

In accordance with the SCDOT Seismic Design Specifications (SDS) for Highway Bridges, the Bridge Operational Classification (OC) for new bridges on Interstates I-26 and I-126 or their Ramps is "I" and all other new bridges is "II."
Prestressed concrete girder superstructures use "I" shaped prestressed concrete girders, while steel welded plate girder superstructures use "I" shaped structural steel girders. Both steel welded plate girder and steel rolled beam superstructures use AASHTO M 270 compliant structural steel, which is painted in accordance with Section 710 of the Standard Specifications.

Phase 1 structure sections with ASTM A1094 CRR

The South Carolina Department of Transportation (SCDOT) recognized the use of galvanized rebar in bridge superstructures as a valuable asset for their high-profile CCR project. SCDOT sought to prioritize the longevity and low maintenance requirements for the new bridges, making A1094 an attractive option. The Archer-United Joint Venture received a recommendation from Infrastructure Consulting & Engineering to consider A1094 as a substitute for ASTM A767 hot dip galvanized reinforcement. A1094's exceptional corrosion resistance, streamlined supply chain, and logistics made it a top contender and SCDOT approved it. Additionally, the availability of mill lengths beyond 60 feet /18+ meter significantly benefits longer bridge projects, reducing the number of splices required.

The procurement portion plays a major role in the approval of A1094, due to the ability to have staged rebar ready for fabrication and respond to last minute changes and minimize lead times is a big deal on large projects. Also, unlike in case of A767 reinforcement, the A1094 steel is rolled and galvanized at the Mill, meaning that product comes directly from the Mill to the fabricators which helps expedited deliveries.

To meet the SCDOT Seismic Design Specifications for Highway Bridges, the base material of A1094 Continuous Galvanized Rebar is ASTM A-706 grade 60, low-alloy steel deformed rebar.

Figure 4. Corrosion protection

2.1.3 Corrosion Protection

~~Provide corrosion protection in accordance with the BDM.~~

Provide galvanized rebar in all new bridge decks and their concrete appurtenances including barriers and sidewalks on this project. See "Galvanized Reinforcing Bars" special provision in Exhibit 5. Galvanizing is not required on steel studs, beam stirrups, or diaphragm reinforcement extended into decks.

The maximum length for galvanized reinforcing bars is 60 feet.

EXHIBIT 5 – SPECIAL PROVISIONS AND CONTRACT REQUIREMENTS

703.2.3.1 USE, TESTING, PRODUCTION, AND BASIS OF ACCEPTANCE

Use zinc-coated galvanized deformed steel reinforcing bars in structural concrete where required by Exhibit 4 and to the limits shown in the Plans. Provide zinc-coated reinforcing steel in structures that is hot-dip galvanized in accordance with ASTM A 767, Class I Coating. Galvanize the steel bars after fabrication and after shop-bending of bent bars.

Source: SCDOT: RFP Final with Addendum 6

The total length of bridges along the I-26 to I-20 Future Ramps is 2.66 miles or 4.28 kilometers. Steel H Bearing Piling and Steel Sway Braces are hot dip galvanized in accordance with ASTM A 123.

Figure 5. Summary of estimated quantities

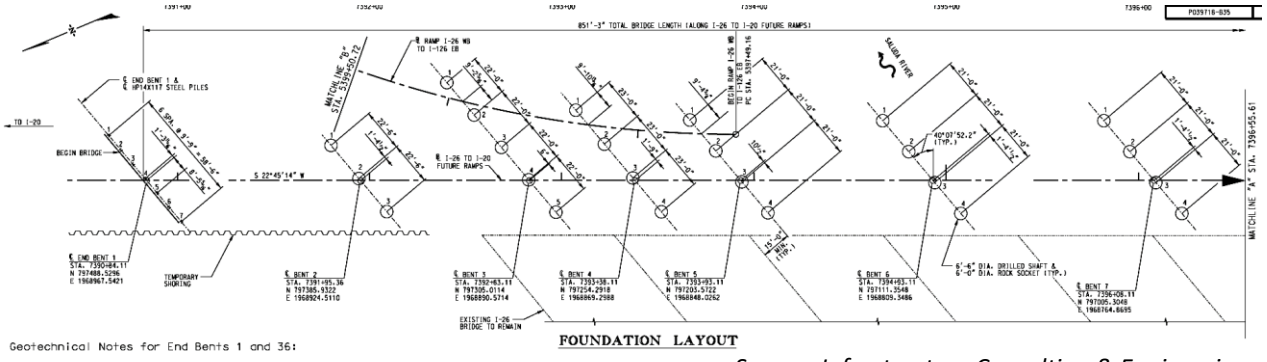
TABULATION OF ESTIMATED QUANTITIES

LOCATION / ITEM	NO.	STUCTURE EXCAVATION FOR RETAINING WALL	TEMPORARY SHORING WALL	BRIDGE DECK LIGHTING SYSTEM	2.0" SCHEDULE 80 PVC CONDUIT	CONCRETE FOR STRUCTURES – CLASS 4000	COMPRESSION SEAL JOINT	GROOVED SURFACE FINISH	REINF. STEEL FOR STRUCTURES (BRIDGE)	HOOP REINF. STEEL FOR STRUCTURES (BRIDGE)	GALVANIZED REINF. STEEL (BRIDGE)	PRESTRESSED CONCRETE BEAM (TYPE II)	PRESTRE CONCR BEA (TYPE
		CY	LF	LS	LF	CY	LF	SY	LBS.	LBS.	LBS.	LF	LF
SUPERSTRUCTURE	1	--	250	1	26,537.1	6,077.1	327.1	16,513	107,822	--	1,402,964	1,725.7	6,70
END BENTS 1, 10 AND 36	3	--	--	--	--	152.5	--	--	28,610		--	--	--
INTERIOR BENTS 2-9, 11-34	32	--	--	--	--	2,382.1	--	--	1,284,079	315,302	--	--	--
INTERIOR BENT 35	1	--	--	--	--	110.6	--	--	70,734	16,847	--	--	--
APPROACH SLAB NO. 2 AND 3	2	--	--	--	172.0	89.2	--	--	--	--	31,453	--	--
SLEEPER SLAB NO. 1 AND 2	2	--	--	--	--	28.8	136.6	--	--	--	4,844	--	--
MSE WALL NO. 1	1	1,000	--	--	--	--	--	--				--	--
TOTALS		1,000	250	1	26,709.1	8,840.3	463.7	16,513	1,491,245	332,149	1,439,261	1,725.7	6,70

Source: Infrastructure Consulting & Engineering

Total quantity of A1094 reinforcement used in the I-26 to I-20 Future Ramps and Ramp I-26 WB to I-126 EB Bridge Over Saluda River and CSX R.R. is 1.439 Milion LBS, or 720 tons.

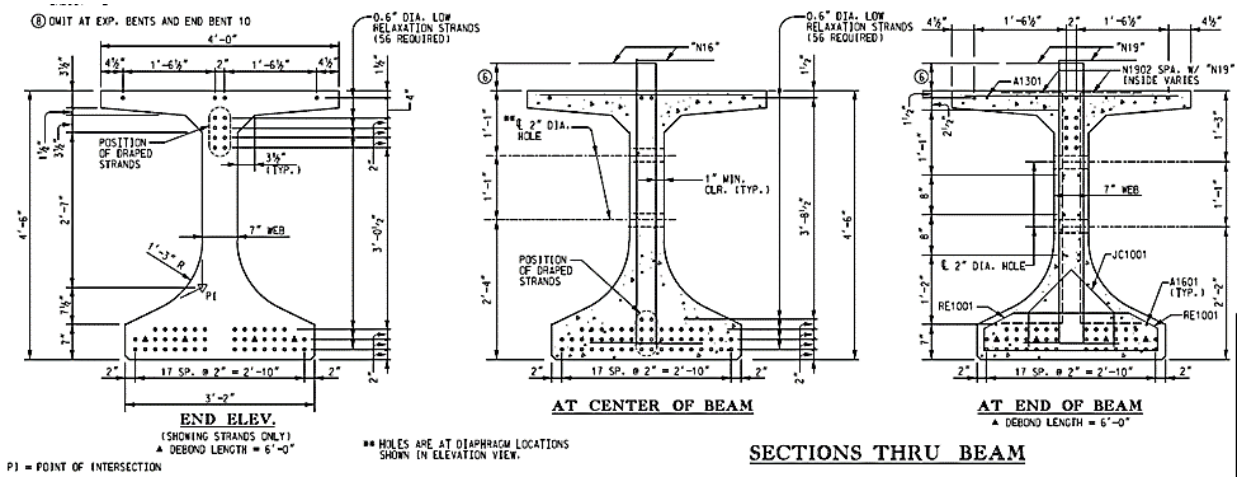
Figure 6. Foundation layout



Source: Infrastructure Consulting & Engineering

Prestressed concrete beams are used with strands that conform to AASHTO M203 for grade 270 low relaxation. Beam Types used: PSC Florida I-Beams 54", PSC Type III, PSC Type IV, PSC Type V, Psc Bulb Tee Beams 54" Mod and Class 9,000 Concrete.

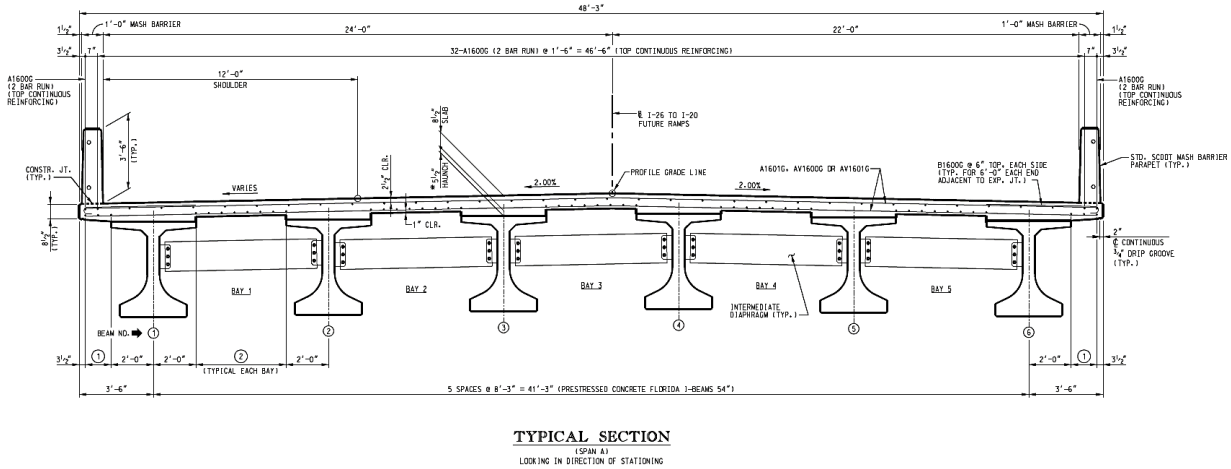
Figure 7. Prestressed concrete beam details



Source: Infrastructure Consulting & Engineering

All bridge deck slabs and concrete appurtenances like barriers and sidewalks require A1094 Continuous Galvanized Rebar.

Figure 8. Typical section



TYPICAL SECTION
(SPAN A)
LOOKING IN DIRECTION OF STATIONING

Source: Infrastructure Consulting & Engineering

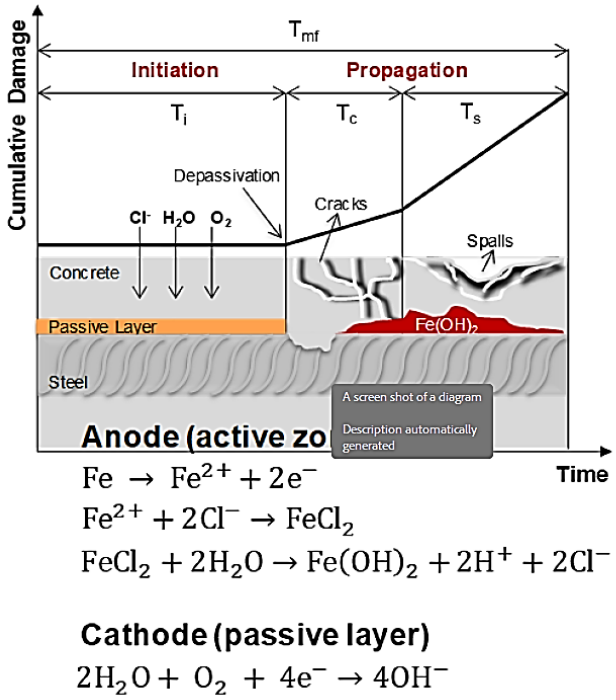
What is A1094 corrosion-resistant reinforcing steel?

Galvanized coatings are commonly used in applications where long-term corrosion resistance is necessary. Some of the most significant markets for this type of coating include highway guardrails, utility poles, sign structures, automobiles, solar panels, as well as truck and trailer components, and there are plenty of vendors available to serve these markets.

However, when it comes to concrete and steel reinforcement, the use of ASTM A767 traditional Hot-Dip Galvanizing (HDG) has been slow to gain traction, and there are limited regional vendors. One of the main concerns is the ability to maintain consistent quality and availability while delivering a product that meets customer demands. These barriers have limited the further adoption of galvanized rebar.

Producing galvanized rebar poses both cost and production challenges. Traditional galvanizing processes do not lend themselves well to fabricating rebar. The number of pieces, shapes, lengths, bundling, tagging requirements, and the need for quick turnaround times make it difficult to provide rebar in a cost-effective and customer-friendly manner.

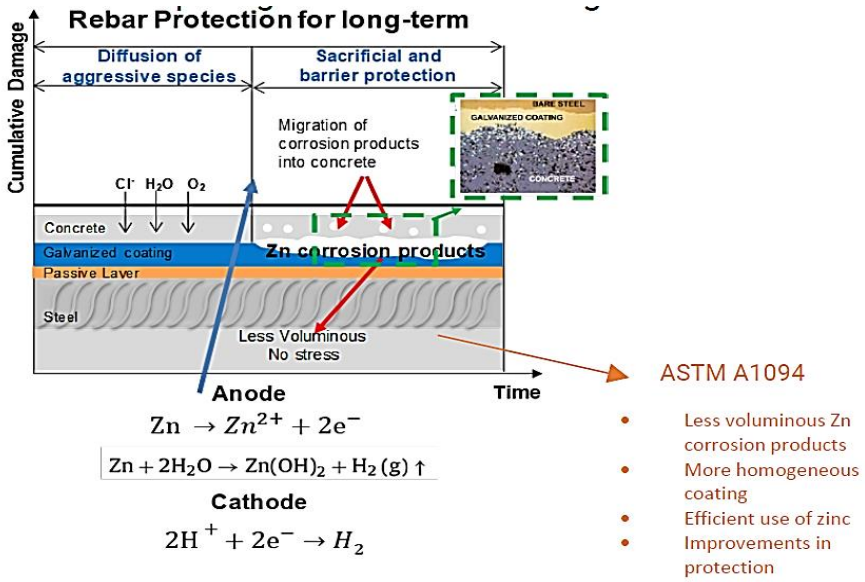
Figure 9. A767 rebar propagation chart



Source: Faza S, "Continuous Galvanized Rebar Pure Zinc, Pure Innovation" white paper.

ASTM A1094 Continuous Hot-Dip Galvanized Steel Bars for Concrete Reinforcement (CGR) was developed as a highly automated galvanizing method, similar to the continuous galvanized sheet process. The modernization of the galvanizing process allows for operational efficiencies that reduce the facility's carbon footprint with a lower embodied energy output, and the on-demand system allows for more efficient use of zinc and utilizes lead-free resources.

Figure 10. A1094 rebar propagation chart



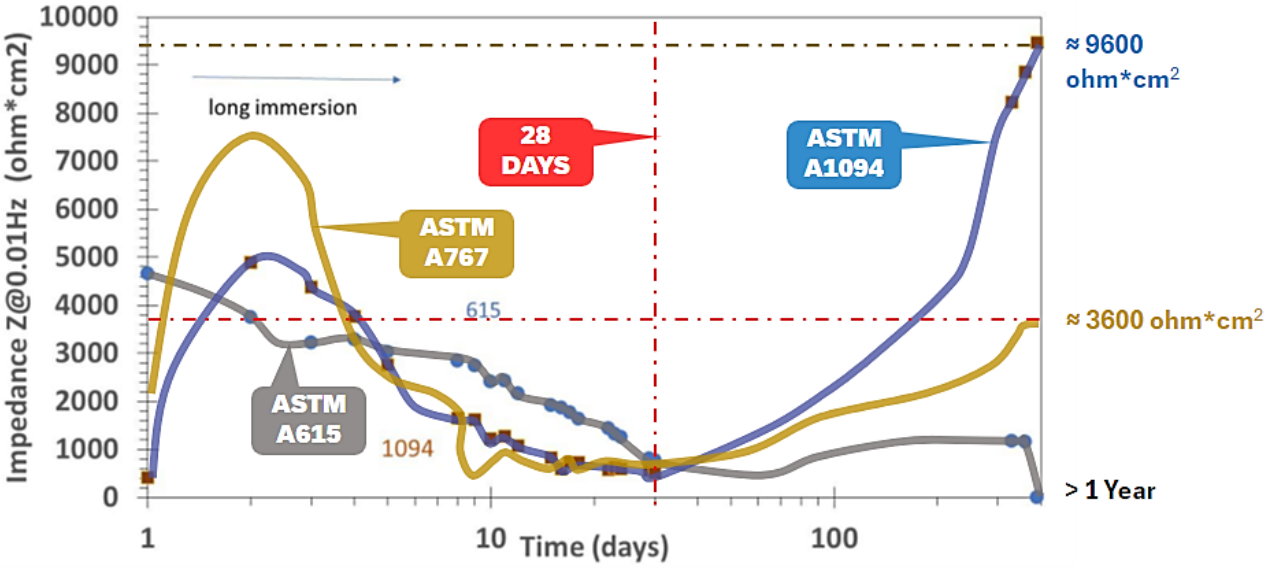
Source: Faza S, "Continuous Galvanized Rebar Pure Zinc, Pure Innovation" white paper.

The Continuous Galvanized Rebar (CGR) process involves mechanical cleaning, induction pre-heating, and galvanization of rebar in an inert environment. This process creates a repeatable, controlled, metallurgically-bonded coating of pure zinc that averages 70 microns, regardless of the steel composition. The mechanical cleaning and induction pre-heating processes eliminate any potential concerns for strain-age or hydrogen embrittlement of steel. This is particularly important for any potential field adjustments or post-galvanized ASTM A767 HDG product fabricating.

The continuous galvanization process provides many benefits, resulting in a product that can be fabricated like uncoated "black" rebar. With CGR, fabrication can be done after galvanization without the risk of peeling or flaking, making it possible to be staged in customizable inventory. This allows for an effective nationwide supply chain through steel mills, fabricators, and distributors. These logistical advantages contribute to CGR's sustainability. The pure zinc coating provides proven protection that dates back hundreds of years. CGR addresses the problematic last-mile issues in the current corrosion-resistant rebar market, demonstrates excellent corrosion resistance in corrosive environments, and is a low-cost corrosion solution for owners.

Recent federally funded research on mechanistic performance shows that A1094 CGR produces a reliable thickness with consistent quality. The thicker pure zinc coating layer of 1094 vs. 767 zinc-iron intermetallic coating layer yields an improved critical chloride corrosion threshold. This unique attribute creates the capability to form a consistent ductile layer that can be fabricated after the coating process. Where A767 is specified A1094 can be used interchangeably with potential for service life improvements.

Figure 11. Corrosion rate comparison of A1094 vs A767



Source: Tran-SET study "Corrosion Management System of Regional Reinforced Concrete (RC) Bridges"

Conclusions

The Carolina Crossroads project is a major infrastructure design-build project in the state of South Carolina. It will cost around US$2.08 billion and will span several years. The project involves renovating a total of 14 miles of I-20, I-26, and I-126, which is also known as "Malfunction Junction." This project is part of the South Carolina Department of Transportation's (SCDOT) 10-Year Plan, which is divided into five phases.

Phase 1 of the project aims to revamp and establish a new junction for Colonial Life Boulevard at I-126 while also addressing necessary enhancements to I-26 and I-126 to ensure optimal safety and efficiency. In order to provide a safer and more efficient alternative, Archer-United will replace the current adverse weave on I-26 westbound between I-20 and I-126 with a semi-directional interchange. This phase spans an approximate distance of 2.66 miles or 4.28 kilometers and will involve the reconfiguration of the secondary frontage roads, construction of three new bridges, and rehabilitation of two existing bridge decks.

Our focus in this paper is Phase 1 and specifically Project ID P03971, which comprises the I-26 to I-20 FUTURE RAMPS and the construction of the I-26 WB to I-126 EB bridge over the Saluda River and CSX R.R.
Galvanized Rebar is mandatory for all deck slabs and concrete appurtenances such as barriers and sidewalks. The South Carolina DOT chose A1094 as a substitute to A767 due to its resistance to corrosion, low maintenance requirements, and streamlined logistics.

The procurement portion played a major role in the approval of ASTM A1094 because the ability to have staged rebar ready for fabrication, respond to last-minute changes, and minimizing lead times is critical on large projects. Also, unlike in the case of A767 reinforcement, the A1094 steel is rolled and galvanized at the Mill, A1094 is rolled and galvanized at the Mill; the product comes directly from the Mill to fabricators and can be fabricated like uncoated "black" rebar.
Additionally, the availability of mill lengths beyond 60 feet /18+ meters benefits longer bridge projects, reducing the number of splices required.

How does the Carolina Crossroads project benefit from the use of A1094 reinforcement?

The continuous galvanization process (CGR) combines zinc's corrosion protection with exceptional formability without peeling or flaking, leading to a product that can be fabricated like uncoated "black" rebar.

Galvanized prior to fabrication, ASTM A1094 allows for seamless procurement of corrosion-resistant rebar utilizing existing supply chains — ready for fabrication and delivery straight to the job site.

Recent federally funded research on mechanistic performance shows that A1094 CGR produces a reliable thickness with consistent quality. The thicker pure zinc coating layer of 1094 vs. 767 zinc-iron intermetallic coating layer yields an improved critical chloride corrosion threshold. This unique attribute creates the capability to form a consistent ductile layer that can be fabricated after the coating process. Where A767 is specified A1094 can be used interchangeably with potential for service life improvements.

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