US Highway 17 Hutchinson Island interchange: low-density cellular concrete embankments over soft soils in Savannah, Georgia

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Abstract. Low-density cellular concrete (LDCC) is increasingly used as a lightweight embankment fill to reduce dead load and control settlement over soft soils. This case history documents the Georgia Department of Transportation's first LDCC application on highway ramps founded on deep marsh deposits at the US 17 Hutchinson Island Interchange in Savannah, Georgia. Hutchinson Island is underlain by 30 to 35 feet (9–11 meters) of very soft, highly compressible marsh clay overlying sand and marl. Two loop ramps were reconstructed: the East Ramp (1999) and West Ramp (2001), both founded on geofabric-reinforced platforms and wick drain improved soft clay topped with LDCC placed in one to two-foot (0.3–0.6 m) thick lifts. The LDCC has a unit weight of 27 pcf (432 kg/m³) and a minimum compressive strength of 40 psi (276 kPa). Long-term performance diverged. The East Ramp remained stable for more than 25 years. The West Ramp developed longitudinal pavement cracking within three years, linked to localized differential settlement where new embankment abutted a 1954 embankment, shortened consolidation waiting periods, missing reinforcement layers, and local LDCC fracturing. The project highlights LDCC's potential and limitations: success requires completing primary consolidation, integrating transitions with the previous embankments, and reinforcing LDCC to bridge differential settlements.

1 Introduction

During security preparations for the 2004 G8 Summit, the White House Secret Service reported a significant pavement crack on a ramp of the US 17 Hutchinson Island Interchange in Savannah, Georgia. The interchange had been reconstructed in 2001 using low-density cellular concrete (LDCC) and other ground improvement measures to address very soft marsh soils. This paper reviews subsurface conditions, geotechnical challenges, subgrade improvements, LDCC embankment construction, and long-term performance, contrasting the satisfactory East Ramp with the cracked West Ramp.

US 17 traverses the eastern seaboard through historic Savannah, Georgia, and Charleston, South Carolina. After crossing the Savannah River, the interchange connects to a cable-stayed bridge via embankments up to 20 ft (6.10 m) with two symmetric loops (East and West Ramps) over low-lying marshland (Fig.1). The interchange and river bridge were originally constructed in 1954. At that time, the very soft marsh deposits were completely dredged out and backfilled with river sand, effectively controlling settlement and stability—an approach that predated modern environmental restrictions on dredging and wetlands.

The 2001 reconstruction modified ramp alignments: the East Ramp was relocated and built largely over virgin marsh (the original 1954 embankment was removed to create wetlands for mitigation); the West Ramp retained portions of the 1954 embankment and expanded northward over marsh (Fig.2).

This produced highly variable subsurface conditions beneath the new embankments, necessitating rigorous ground improvement design.

2 Site and subsurface conditions

2.1 Regional setting and investigations

Three rounds of geotechnical investigation were performed for two stages of construction. As shown in Fig.1, a Georgia Power transmission line crosses the interchange with eight towers at four stations. Borings at these towers—advanced via mud rotary methods using a CME 45 rig after placing matting over the marsh—showed subsurface conditions unaffected by interchange construction.

2.2 Stratigraphy and geologic context

Transmission tower borings revealed 30–35 ft (9–11 m) of very soft organic clay and silt (marsh mud), 20–25 ft (6–8 m) of loose to medium dense sand, and stiff clay (marl) beneath. Geologically, the salt marsh formed

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during the late Holocene (~last 4,000 years) as sea-level rise slowed; the sand layer is Pleistocene in age, and the stiff marl is Miocene in age. The marl extends from ~60 ft to ~200 ft (18.3–61.0 m) and provides a competent formation for deep foundations in the area.

Fig.1. Overview of US 17 Hutchinson Island interchange.

2.3 Compressibility and strength

The marsh deposit is very soft, normal to underconsolidated, with OCR slightly less than 1, and exhibits high compressibility. Table 1 lists typical ranges of marsh deposit parameters from laboratory consolidation and strength testing.

Calculated total consolidation settlements for conventional embankments of 10–20 ft (3.05–6.10 m) ranged 38–57 in (97–145 cm). Stability analyses indicated the marsh could not safely support >5 ft (1.52 m) of fill at typical angles of repose (35–40°). To maintain stability to prevent mudwave (lateral movement), super-flat slopes of 13:1 and 17:1 would be required for 10 ft (3.05 m) and 20 (6.10 m) ft embankments, respectively, assuming undrained shear strength of 200 psf (9.6 kPa).

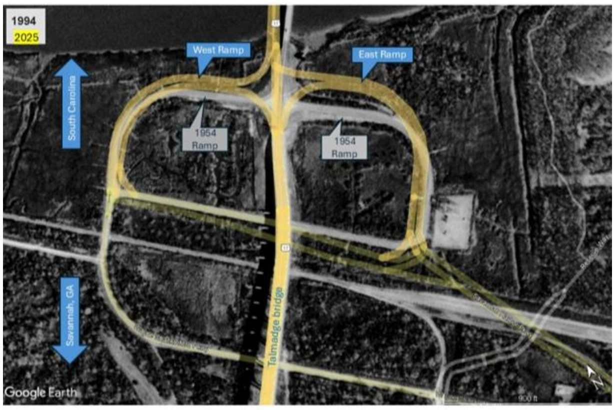


Fig. 2. Ramp layout relative to 1954 ramps.

3 Embankment reconstruction: options and selected design

3.1 Historical approach (1954)

The 1954 interchange mitigated settlement and stability risks by dredging out ~30 ft (9.14 m) of soft marsh and backfilling with pumped sand. While effective, this approach is now costly and incompatible with modern environmental regulations on wetland and dredging.

Table 1. Soft soil (marsh deposit) parameters.

Soil Parameters	Worst Case	Best Case
Initial void ratio	3.4	2.4
Atterberg Limits	LL=130 PI=85	LL=110 PI=66
Organic Content	17%	5%
Compression Index, Cc	1.145	0.75
Dry Unit Weight (pcf) (kg/m3)	37.5 (600)	48.5 (776)
Water Content	130%	85%

3.2 2001 alignment changes and explorations

Fig.2 overlays 2025 and 1994 aerial photographs to illustrate alignment changes. Each loop ramp is ~1,500 ft (457 m) long, descending from ~20 ft (6.10 m) near US 17 to ~5 ft (1.52 m) at the low end. Four deep borings, located mostly along the edges of the 1954 embankment, showed medium-dense sand beneath portions of the embankment (consistent with historical sand backfill). Near the toe, borings encountered soft marsh deposits, confirming that the new alignment crossed virgin marsh.

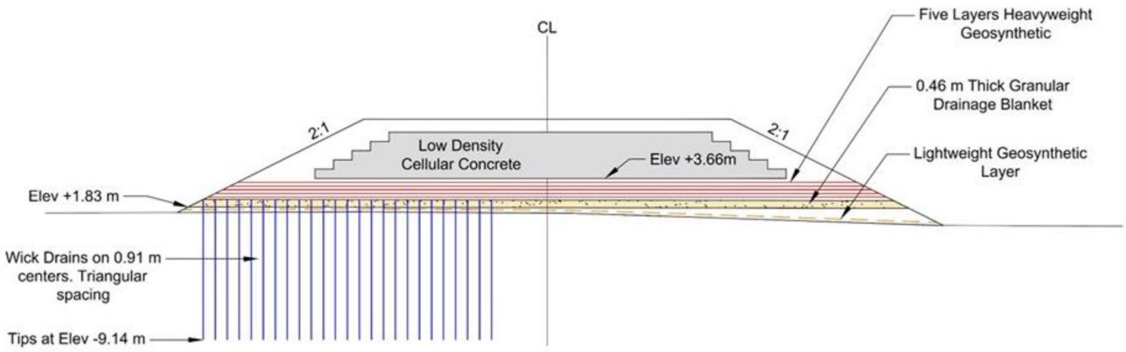
3.3 Evaluated alternatives

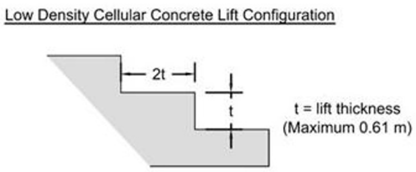
Complete dredge removal: Not viable due to cost and environmental constraints.

Wick-drain preloading with staged construction: Effective but introduces schedule uncertainty.

Counterweight berms: Rejected due to right-of-way needs and wetland permitting.

 https://doi.org/10.1051/e3sconf/202673005007





LDCC Density and Strength		
	Max Density (kg/m³)	Min Compressive Strength (kPa)
Top 0.6 meters	432	276
Below 0.6 meters	624	827

Fig. 3. Embankment construction details.

3.4 Adopted ground improvement design

As shown in Fig.3, the embankments were constructed using the following process [1]:

- Vegetation removal and placement of a lightweight geofabric separator.
- Levelling fill to +6 ft (+1.83 m).
- Drainage blanket of 18 in (457 mm) clean sand.
- Wick drains installed to –30 ft (–9.14 m).
- Five heavyweight geofabric layers with 12 in granular layers, forming a platform at +12 ft (+3.66 m). Table 2 lists the strength properties of the lightweight and heavyweight geofabric based on the Georgia DOT Provisions.
- Settlement monitoring prior to LDCC placement. The LDCC was added over the eastern ramp geofabric reinforced platform after the settlement monitoring confirmed the settlement curves had reached an asymptotic state. However, the schedule for the western ramp was controlled by the opening of the conventional center and a hotel. The LDCC had to be added on before the settlement of the geofabric reinforced platform was complete.

4 LDCC material, construction, and pavement

LDCC—composed of cement, water, and a foaming agent—was mixed on site and pumped into place in 1–2 ft (0.30–0.61 m) lifts. Total LDCC thickness ranged 2–7 ft (0.6–2.13 m) on East Ramp and 3–11 ft (0.91–3.35 m) on West Ramp. LDCC has a density of 27 pcf (432 kg/m3) and a compressive strength of 40 psi (276 kPa) except for the upper two feet (0.6 m), which has a density of 39 pcf (624 kg/m3) and a compressive strength of 120 psi (827 kPa). LDCC construction lasted three weeks for the East Ramp (opened 1999) and five weeks for the West Ramp (opened 2001).

4.1 Roadway structure

The pavement structure comprised a levelling layer over LDCC, 8 inches (203 mm) of graded aggregate base (GAB), and 6 inches (152 mm) of asphalt surface (Fig.4).

5 Performance and west ramp crack investigation

5.1 East ramp performance

The East Ramp has performed satisfactorily for >25 years, validating LDCC’s long-term suitability when founded on a reinforced platform with adequate consolidation of the soft clay.

5.2 West ramp distress observations

Approximately three years after completion, the West Ramp developed a longitudinal crack extending from the shoulder to the center of the north lane (Figure 5). Six pavement cores along the crack revealed voids in two cores, shallowly beneath the pavement and up to 12 in (305 mm) in size. Approximately 1.1 cubic yards (0.84 m³) of flowable concrete was injected to fill voids [3].

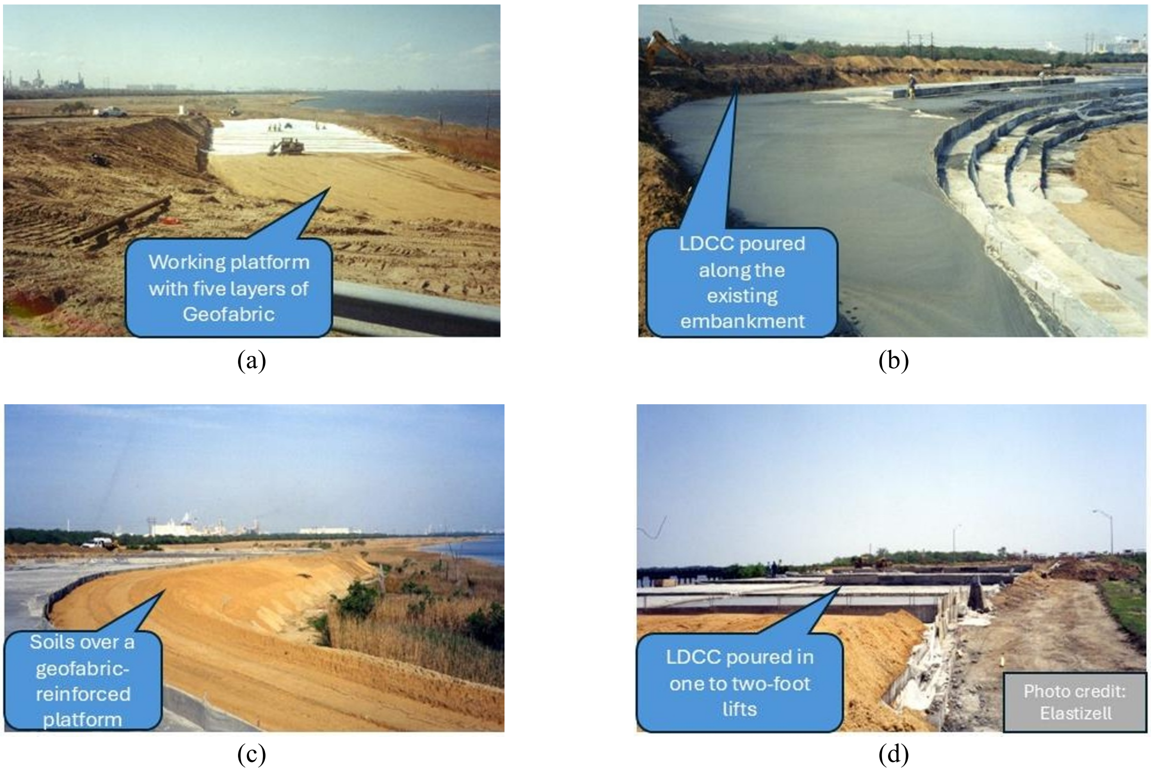


Fig. 4. Embankment construction sequence.

5.3 2004 forensic investigation

A more extensive investigation in 2004 included four 50 ft (15.24 m) borings and 11 hand auger borings to 5–10 ft (1.52–3.05 m). Findings:

- Medium dense sands, not soft clays, underlay the ground below the embankment—consistent with 1954 dredged backfill.
- No geofabric reinforcement was encountered beneath the distress zone.
- Additional voids were found within the LDCC layer.
- Sixty survey points monitored for >6 months showed no movements; the cracked lane was closed for observation.
- No further surface settlements were detected, and pavement elevations remained level. Nonetheless, additional localized surface collapse occurred about eight years later, requiring saw cutting, void filling, and surface reconstruction.

5.4 Interpretation

Distress was not indicative of global slope instability. The evidence supports localized differential settlement where new embankment fill was placed adjacent to the preexisting 1954 embankment. Contributing factors included:

- Shortened waiting time for consolidation under the reinforced platform (to meet opening schedules for the Convention Center and resort).
- Missing reinforcement layers and a lack of structural tie-ins at the transition between the new fill over the wick drained marsh deposit and the pre-existing embankment over backfilled sand.
- Differential load transfer between zones founded on dredged backfill sand vs. wick drained marsh clay.

Local LDCC fracturing, allowing cracks to reflect to the pavement surface.

6 Discussion: lessons

This case history underscores the dual role of LDCC and reinforced platforms: LDCC effectively reduces embankment self-weight and limits the total settlement, while the geofabric reinforced platform provides stability and enables steeper slopes (2:1). However, LDCC's brittleness and low tensile capacity make it prone to crack reflection when differential settlements occur across transitions in foundation conditions.

Key lessons:

1. Complete primary consolidation under the reinforced platform before LDCC placement and pavement construction; maintain instrumented waiting periods guided by settlement plates and pore pressure dissipation.
2. Anticipate transitions between legacy embankments (1954 dredged sand) and new construction (wick drained marsh clay), and design for differential stiffness/settlement.

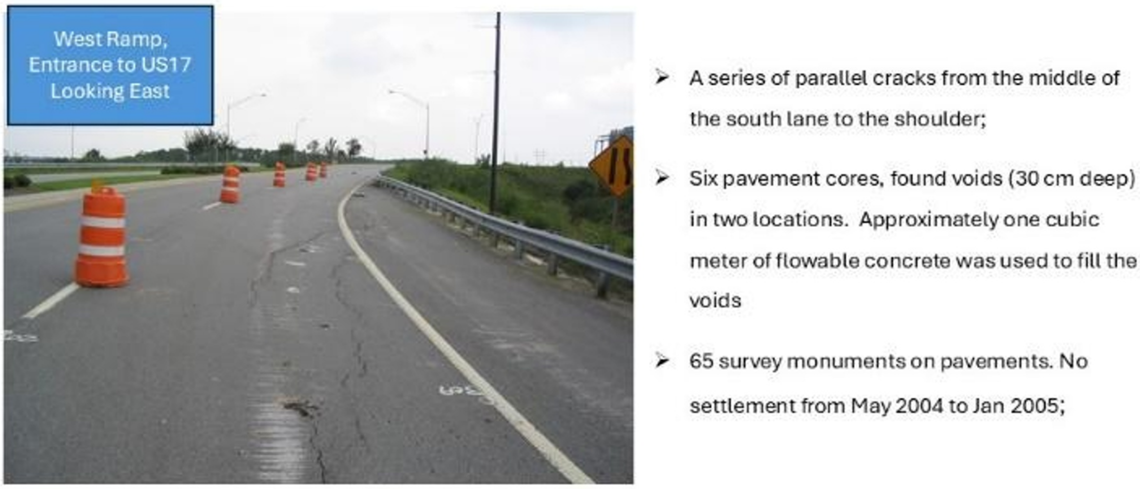


Fig. 5. West ramp pavement cracks in 2004.

Table 2. Strength of geofabric.

Tensile Strength (lb/in) (KN/M)				
	Type A - Lightweight		Type B – Heavy Weight	
Fabric Type	5% Strain	Ultimate	5% Strain	Ultimate
Polyester	200 (35)	250 (44)	670 (117)	1675 (293)
Polypropylene	200 (35)	400 (70)	670 (117)	2680 (469)

3. Provide structural tie-ins—e.g., high-strength geogrid/geofabric, metal or fiberglass ties, or other mechanical connectors—to bridge transitions and distribute shear/settlement strains across the LDCC layer.
4. Detail LDCC with reinforcement or overlays (e.g., geosynthetic interlayers, crack arrestors) where settlement gradients are expected, to mitigate crack reflection to the pavement.
5. Plan staged construction rigorously and avoid schedule-driven compromises that shorten consolidation periods.

7 Future interchange upgrades

The planned development of a container port terminal on Hutchinson Island will require widening and upgrading the interchange for heavy truck traffic and extending embankments further into the marshland. Subsurface conditions will be highly variable, falling into three profiles:

1. 1954 legacy embankment areas underlain by dredged/backfilled sand
2. 2001 improved areas where marsh clay was consolidated by wick drains and surcharge
3. New expansion zones over virgin marsh mud Design should explicitly address total settlement, differential settlement, and slope stability across these transitions. Recommended measures:

- Geophysical testing to detect voids beneath existing roadways (e.g., GPR, seismic surface waves), followed by proofrolling with a heavily loaded truck during reconstruction to identify weak zones.
- Rigid inclusions (e.g., controlled modulus columns, micropiles) in new marsh areas to limit settlement and increase stiffness while minimizing lateral spread.
- Structural tie-ins across interfaces (high-strength geogrid/geofabric, fiberglass/metal anchors) to bridge differential movements.
- Enhanced monitoring (settlement plates, in-place inclinometers, vibrating wire piezometers) to confirm completion of consolidation settlement prior to LDCC and pavement placement.
- Pavement design with interlayers and accommodation for maintenance at known transition zones.

8 Summary and conclusions

The US 17 Hutchinson Island Interchange demonstrates the promise and limitations of LDCC embankments over very soft marsh deposits. The East Ramp has performed flawlessly for >25 years, affirming LDCC's long-term viability when staging and consolidation are properly executed. The West Ramp experienced longitudinal cracking due to localized differential settlement at the interface of 1954 dredged sand and 2001 expansion over marsh, compounded by shortened consolidation waiting periods, missing reinforcement, and local LDCC fracture. Crucially, investigations found no global stability issues.

For future upgrades, success hinges on: (*i*) completing primary consolidation under the reinforced platform; (*ii*) anticipating and designing for transitions between different subgrade profiles; (*iii*) providing structural tie-ins and/or rigid inclusions to bridge settlement gradients; and (*iv*) detailing LDCC and pavement systems to mitigate crack reflection. With these measures, LDCC remains a robust, lightweight solution for embankments over soft soils.

The author acknowledges Mary Cooley and Catherine Armstrong of the Georgia Department of Transportation, Nathaniel Panther and Deana Brooks of Chatham County, former GDOT managers Mr. Brad Saxon and Glen Durrence, Jacob Varner of Moffatt Nichol, Meredith Allen of AECOM, and Terracon colleagues Logan Richard, Chao Zheng, Mike DeMell, and Drew Gaylor for assistance in preparing this paper.

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