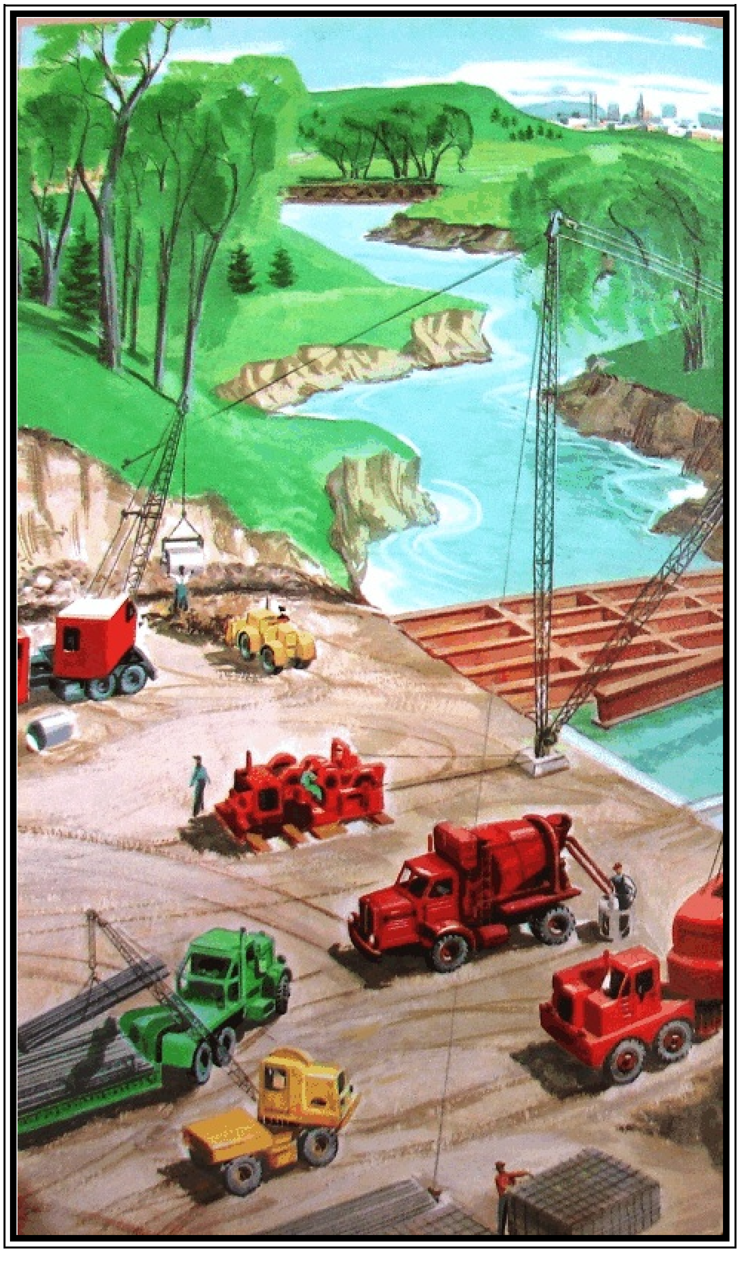
HISTORIC CONTEXT FOR BRIDGE-BUILDING TECHNOLOGY IN GEORGIA, 1955-1965



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Prepared for:

Georgia Department of
Transportation
Project Task Order No. 94
Historic Bridge Survey

July 2007

Detail from Cummins ad, Dixie Contractor (1956).

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The Era of Uniformity in Bridge Design

Georgia's nearly 2,330 extant highway bridges built from 1955 through 1965 reflect bridge-building trends that are marked mostly by uniformity of established, standardized bridge types, like the steel stringer, the reinforced-concrete T beam, and the reinforced-concrete slab. Refinements of this decade included the use of improved materials and details, including the introduction of prestressed concrete. The emphasis was on finding ways to plan, design, and construct a large number of bridges quickly and efficiently, in response to the needs of the interstate highway system. One of the most important developments was the introduction of computer applications to speed the process of designing bridges. Except for the prestressed-concrete bridges, all of the bridge types in the 1955-65 study population are represented in Georgia's pre-1955 study population.

One of the primary reasons for the uniformity of bridge materials, types, and designs is that technical design standards officially adopted by the State Highway Department of Georgia (SHD) had come to govern practically all bridge projects during the study period.[1] Bridges on the Georgia State Highway System (Interstate, US, SR, and FAS routes) were built under the direct authority and supervision of engineers of the SHD who closely adhered to the comprehensive specifications. Only some county and city bridges, usually the shorter, less complex, and thus less costly bridges, were built without state funding, but even then Georgia's local units of government relied heavily on the technical support of engineers and contractors familiar with state standards. Every bridge builder who worked with the SHD signed a contract that included a clause that all work would conform with the published specifications.[2]

Another factor in the uniformity of bridge type and design was the SHD's <u>Geometric Design Standards</u>, first published in 1949 and revised about every five years thereafter. The stated goal was for all of the state's roadways and bridges to meet minimum geometric standards (roadway width, curvature, live loads, vertical clearance, etc.) for the various roadway classifications. As well, the SHD strived to replace existing substandard bridges or improve them so they met the minimum standards. The <u>Standards</u> incorporated national guidance developed by the federal Bureau of Public

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[1] The SHD was the predecessor of the Georgia Department of Transportation (GDOT). It was renamed GDOT in 1972.

[2] C. A. Marmelstein, "Specifications and Their Interpretation," <u>Proceedings of the 12th Annual Georgia Highway Conference</u> (1964), pp. 40-44 (Hereafter cites as <u>Georgia Highway Proceedings</u>; SHD, <u>State Highway Department of Georgia Standard Specifications</u> (1956). The specifications were first published in 1931, and revised in 1936, 1942, 1947, 1956, and 1966. Each revision became progressively "thicker" with Section 500 covering specifications related specifically to bridges and culverts.

Roads (BPR), the American Association of State Highway Officials (AASHO, now AASHTO), and the American Society for Testing Materials (ASTM). Georgia's state bridge engineers played an active role in AASHO committee deliberations, and they assisted in the cooperative development of the standards with bridge engineers from the BPR and other state highway departments. As a result, hundreds of highway bridges from this period across Georgia, and, indeed, across the nation, were technologically indistinguishable from one another.

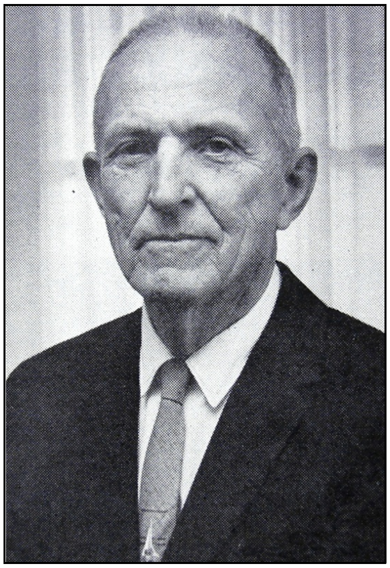
Figure 1. Searcy B. Slack, State Bridge Engineer, 1920-1933. Source: GCGM, 1962.

Inherited tendencies in the SHD's Division of Bridges also played a significant role in the uniformity of bridge design in Georgia. The bridge division had been established in 1920 under the superb leadership of State Bridge Engineer Searcy B. Slack (Figure 1). Over the next 13 years, Slack emerged as a national expert on the use of low-cost, standardized bridges that were functional and unadorned. Under Slack's guidance, personnel in the bridge division became closely attuned to the economics of bridge construction in Georgia, including the cost of materials, the cost and availability of various classes of labor, the cost of transporting materials to bridge sites, and the costs associated with the geology and hydrology typical of Georgia's geographic regions.[3] During the 1920s, Slack favored reinforced-concrete T beam and slab bridges for the preponderance of crossings, and then during the early 1930s he adopted some innovative, standardized, continuous-design and continuous-cantilever-design steel stringer bridges that would prove critical to advancing Georgia's bridge-building program during the Great Depression and beyond.

Slack left the SHD in 1933, yet his successors continued the practices and preferences that he had promoted. Clarence Crocker (Figure 2) who served as state bridge engineer from 1933 to 1955 and Charles Marmelstein (Figure 3) who served from 1956 to 1967 were Slack proteges. They had been recruited by Slack in the 1920s and were among that generation of engineers who made the SHD and the improvement of Georgia's roads and bridges a life-long career. Crocker and Marmelstein were always monitoring, adjusting, and refining the bridge specifications and standard plans so that Georgia "got its money's worth," but they did not try out new bridge types and designs without clear evidence of cost savings. The SHD bridge engineers thus exercised a

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[3] L. E. Mallory and R. S. Fountain, "Bridge Substructures and Foundations," Georgia Highway Proceedings (1955), pp. 128-38. By the mid-1950s, experience had shown that the most economical substructure units were two or more column reinforced-concrete piers, steel pile bents, concrete pile bents, and timber pile bents. The bents tended to be used in softer sediments (typical of the Coastal Plain and Piedmont), while the piers could be founded on rock (typical of the Fall Line and Mountains).

Figure 2. Clarence Crocker, State Bridge Engineer, 1933-1955. Source: Georgia Highways (1958).

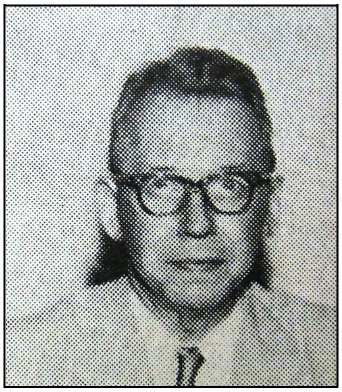

Figure 3. Charles A. Marmelstein, State Bridge Engineer, 1956-67. Source: Georgia Highways (1958).

conservative approach to bridge type selection during the study period, relying heavily on a few bridge types, particularly the standardized steel stringer, T beam, and slab that had proven their ease of design and economy of construction during the first half of the 20th century.

The reason that standardization worked so well was a marriage of technical, economic, and political considerations that had been influencing bridge-building trends in Georgia since the early 20th century. Standardization allowed for quality control across the entire state. Cost comparisons and accurate estimates could be made from project to project, thus serving as a check on contractors. Innovative or untried, individualistic bridge plans tended to introduce unpredictable costs into a bridge project, something no one favored. Standard design details and specifications also helped the SHD obligate federal-aid funds, since once approved the first time they were unlikely to be held up to extra scrutiny by federal engineers. After 1956, state engineers were under tremendous political pressure to advance projects, especially interstate highway projects, to meet the political and public demands for the new freeways, and standardization helped them in the face of manpower shortages while at the same time delivering an unprecedented number of new bridges. It was a remarkable accomplishment, but one that resulted in very few individually outstanding bridges.

The decision of which bridge type to use was most often a reflection of site conditions (e.g., the length of span required, vertical clearance, foundations, classification of roadway, etc.), the current cost of materials, and to some lesser degree the individual preferences of the designing engineer and contractor. Decisions were, however, based almost always on the technical information and specifications developed by the SHD, with input from national trade and research associations, like the American Concrete Institute (ACI), the Portland Cement Association (PCA), and the American Welding Society (AWS). Georgia's bridge engineers met regularly with federal engineers and representatives of academia, private industry, and government at meetings of the Georgia Annual Highway Conference,[4] the Southeastern Association of State Highway Officials (SASHO), the Georgia County Government Association, and the like. Standards and specifications were a frequent topic of review and comment at the conferences. And as State Bridge Engineer Charles A. Marmelstein commented in 1964, one of his primary jobs was writing specifications. He made it a rule "don't

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[4] The Annual Highway Conference was held starting in 1951 at Georgia Tech. It brought together SHD engineers, university faculty and students, and private engineers and contractors.

specify the impossible, and don't specify anything not intended to be enforced." This approach enabled state, county, and city engineers to achieve quality and economy in their bridge designs, utilizing best practices and sound engineering principles. It also provided contractors assurance that standards and specifications would not vary greatly from job to job.[5]

Figure 4. Jackie Harmon, a SHD employee, poses at the IBM 650 (left) and the card reader (right). Source: Georgia Highways (1958).

Significantly, the standardized approach to bridge design that had developed in Georgia was a natural fit with the burgeoning era of computerization. In late 1955, state bridge engineer Charles Marmelstein realized that the impending interstate highway program would create a crisis in the bridge division. There simply weren't enough engineers to complete all of the work and no hope of recruiting enough sufficiently experienced engineers. He advocated speeding up the design process by using a main-frame computer to perform calculations then being completed by hand. Since WWII, computers had proven that they could perform this kind of work, especially for the military, and IBM had introduced a new generation of business computers that were increasingly affordable for industry and government. In 1956, the SHD arranged to purchase an IBM 650 computer, and the bridge division immediately assigned two of its engineers – Russell Chapman and Jose M. Nieves – to develop a program that would use input from punch cards to perform the calculations needed to design skewed, super-elevated bridges. This program proved so accurate and successful that other programs were soon developed, including those for calculating the moments in continuous-design bridges and in substructure units, and for more accurately tracking and estimating construction costs. These programs cut down significantly on time spent on complex calculations. The computer could do in a few hours the work that had previously taken state engineers days and days. Marmelstein demonstrated complete confidence in the computer and Georgia emerged as a national leader in the application of computerization to bridge design in the late 1950s. Doug Hudson, an engineer who joined the bridge division in 1947, recalls that the computer's contribution was "miraculous" and that he doesn't think that the division could have competed the bridge designs for the interstate highway system without it.[6]

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[5] American Association of State Highway Officials, Standard Specifications for Bridges (Washington: 1957); Marmelstein (1964), p. 44.

[6] SHD; Biennial Report (1957-58), pp. 107-08; (1959-60), p. 105; Doug Hudson, Personal Communication with P. Harshbarger (July 1, 2007); "The Story Behind the Figures," Georgia Highways (Dec. 1958), pp. 1-3, 15.

Computerization wasn't the only new technology employed by Georgia bridge engineers in the late 1950s. In 1957, SHD bridge engineers introduced the state to a new bridge material – prestressed concrete. They constructed about 100 prestressed-concrete bridges from 1957 to 1965, but unlike the efforts in computerization, Georgia was not known as a national leader in the development of prestressed concrete. While prestressed-concrete beams and pilings were easily standardized, Georgia's state bridge engineers repeatedly found that the prestressed-concrete bridges did not offer significant cost advantages over traditional steel and reinforced-concrete bridges, and, in fact, often cost slightly more. Georgia did not have a strong prestressed-concrete bridge fabricating industry, nor did state officials feel the need to foster it like some states did as a viable alterative to steel or reinforced concrete. After 1958, the SHD built a handful of prestressed-concrete bridges, but all of its bridges used the standardized beam designs that had been approved by AASHO and the BPR in 1954-56 for use throughout the United States. These designs had been tested, refined, and approved by AASHO and BPR engineers for use on federal-aid projects, not developed in-house by Georgia engineers. Thus, there was rarely anything innovative about the early and limited use of prestressed-concrete bridges constructed in Georgia before 1966.[7]

Bridge Types on Georgia's Non-Interstate Highway Systems, 1955-65

The extant 1955-65 bridges on Georgia's non-interstate highway systems are, with few exceptions, steel stringer, reinforced-concrete T beam, or reinforced-concrete slab.[8] Of the 1,825 inventoried non-interstate bridges, 39% are steel stringers, 36% are T beams, and 21% are slabs. The remaining 4% represent a variety of other bridge types, including prestressed concrete, bascule, girder-floorbeam, and truss (Table 1). All of the bridge types, except the prestressed-concrete bridge types, were introduced and refined in earlier periods and are well represented in Georgia's pre-1955 historic bridge population.

The SHD designed all primary federal-aid highway system bridges (IR, US, and most SR routes) during the 1955-65 study period for 36-ton semi-truck design vehicles (H-20, S-16).[9] Based on this load-carrying capacity and typical span lengths and widths

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[7] Ibid.

[8] Interstate highway bridges are excluded from the study because of the national interstate Section 106 eligibility exemption signed in February 2005 by FHWA and the Advisory Council on Historic Preservation. The bridge types on the interstate system were, however, reviewed and reflect, in general, the bridge types found on the other state highway systems.

[9] These codes are a standard system for designing and rating bridges using a theoretical design vehicle. AASHO's Bridge Committee, whose members were state and federal bridge engineers, adopted the system in 1931 and a modified version of it remains in use today. Most states, including Georgia, have used the system or a variation of it since 1931. H-20, S-16 (or HS-20), for example, refers to a bridge that has a live-load design or rating for a semi-truck with a gross-vehicle weight of 36 tons. Other common H-loadings were for H-10 (10-ton, two-axle truck) and H-15 (15-ton, two-axle truck). FHWA,

Bridge Type	Total No. of Examples on Georgia's Non-Interstate Highway Systems, 1955-65
Steel Stringer	707
Reinforced Concrete T Beam	650
Reinforced Concrete Slab	386
Prestressed Concrete Stringer	24
Prestressed Concrete Slab	18
Wood Stringer	11
Steel Girder-Floorbeam	9
Prestressed Concrete Channel Beam	6
Steel Truss	6
Prestressed Concrete Box Beam	4
Reinforced Concrete Channel Beam	2
Bascule	1
Other Types (not specified by NBI)	1

Table 1: Bridge Types on Georgia's Non-Interstate Highway Systems. Source: GDOT, National Bridge Inspection (NBI) database, 2007.

(minimum of 28'), the generally preferred bridge types selected by state engineers based on prevailing conditions and tendencies in Georgia were rolled steel beams or cast-in-pace reinforced-concrete T beams. Selection of steel or reinforced concrete tended to be based on fluctuations in price and availability of material due to variations in demand and production at the mills. Georgia's secondary roads and county roads designed for a minimum live-load capacity of 15-ton design vehicle (H-15) during the study period, and this condition, along with generally shorter span lengths of local bridges, lower volume roads, and narrower roadway widths (minimum of 22'), favored a

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America's Highways, 1776-1976 (Washington, D.C., 1976), p. 432.

slightly different mix of bridge types, predominantly steel beam or precast reinforced-concrete slab.[10]

Steel Bridges

Steel Stringer Bridges

Nearly half of all bridges built in Georgia from 1955 to 1965 were steel stringer bridges. Undoubtedly the percentage would have been even higher if demand for steel had not been so high and delays in delivery common. The main drawback to steel bridges during the 1950s and 1960s was that the steel industry did not keep up with high demand, did not invest in more efficient equipment, often had steel diverted to high-priority defense work, and had production problems because of labor strikes. These circumstances resulted in many frustrating delays for bridge engineers and contractors in Georgia, as well as throughout the nation, and encouraged them to use reinforced-concrete or prestressed-concrete bridge types as an alternative to steel.[11]

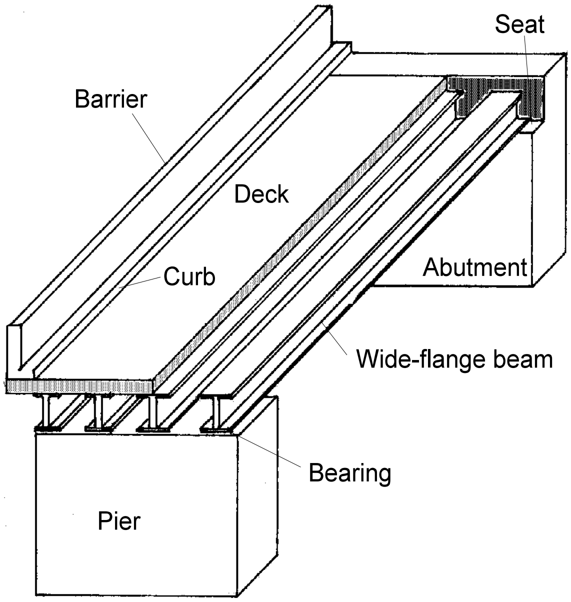

Figure 5. Typical steel stringer bridge.

The SHD built the majority of steel stringer bridges, and its strategy of using standard designs changed little from the 1930s through the 1960s. The versatility of the steel stringer bridge type was that it could be easily proportioned and the beams spaced out to support typical live loads and lengths up to 65' for simple spans using rolled sections and over 150' for continuous or continuous-cantilever designs using built-up sections. The dominance of the steel stringer technology is so complete that even to this day no other highway bridge type comes close to being as common. As a population, the steel stringer bridges are highly undifferentiated. They reflect the successful and unvarying application of standard bridge plans and specifications to highway system development, but individually they are rarely remarkable.

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[10] SHD, Geometric Design Standards for Use on Location and Design (1961).

[11] Forester Booker, "Bridge Superstructures," Georgia Highway Procedings (1956), pp. 93-100; E. L. Erickson, "Bridge Design in View of Present Steel Situation," Proceedings of the Southeastern Association of State Highway Officials (1956), pp. 101-07. Hereafter cites as SASHO Proceedings.

The steel stringer bridge type (also known as multi-beam or multi-girder) consists of a series of parallel longitudinal steel beams supporting a deck, usually of reinforced concrete (Figure 5). A stringer bridge relies on the bending strength of the beam to resist loads. Beam depth is determined by the length of span, beam spacing, and design load – the longer the span, the wider the spacing between the beams, and/or the heavier the load, the deeper the required beam. Some of the most important advances in steel stringer bridge technology have thus occurred in mills and labs where engineers and scientists have sought to improve or refine beam metallurgy. These refinements have included the introduction of particular steel alloys for longer, deeper, stronger, and/or lighter beams, for better withstanding the weather, for welding, and for high-tensile connections. By the 1910s and 1920s, steel beams were proving to be the workhorses of American bridge-building practice. Consequently, steel manufacturers and engineers working through the American Steel Institute (ASI) and the American Society for Testing Materials (ASTM) successfully developed improved metallurgy for specific structural applications, and bridge builders readily took advantage of these improvements resulting in higher strength beams. During the 1950s and 1960s, for example, the primary focus was on developing high-strength steels better suited to longer span bridges using welded beams rather than riveted beams because of savings in material and labor. With higher yield strengths and resistance to corrosion, these new steels allowed bridge engineers to design longer spans using less steel, thus reducing the overall costs of the materials used in bridge construction.[12]

Figure 6. Erecting a steel stringer bridge near Albany. Source: Dixie Contractor (1960).

The popularity of the steel stringer bridge type has its roots in the late 19th century. From the 1890s through 1910s, successive innovations allowed steel mills to roll longer and deeper I-shaped beams. By 1920, most of the major hurdles in manufacturing wide-flange steel beams of up to 36" depth and 60' long had been overcome. Prices for the rolled beams fell through the following years, increasing competitiveness with other materials such as wood, reinforced concrete, or built-up steel beams (see below). The rolled beams were a boon to bridge builders and proved ideally suited for the highway-building campaigns of the

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[12] FHWA, America’s Highways (1976), pp. 434-39; B. R. Queneau, “Properties and Price Relationship of Structural Steel for Bridges,” and F. K. Goodell, “Application of High Strength and Low Alloy Steel in Bridge Design,” SASHO Proceedings (1957), pp. 60-64; The Making, Shaping, and Treating of Steel, Sixth Ed. (Pittsburgh: US Steel, 1951).

20th century. Rubber-tired trucks and improved heavy-construction equipment eased the problems of transporting the beams and on-site erection (Figure 6). With primarily accessible flat surfaces, steel stringer bridges were easier to clean and paint than trusses. They also did not require the labor, form work, and curing time of cast-in-place reinforced-concrete bridge types. The rolled steel stringer bridges also had the advantage of being easy to widen, and the beams could be salvaged and reused if a bridge were replaced. For these many reasons, by the 1930s in Georgia and elsewhere the rolled steel stringer bridge type was becoming the preferred bridge type for use on the development of state highway systems.[13]

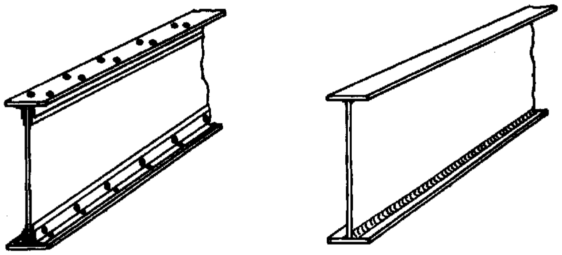

Figure 7. Built-up riveted beam (left) and welded beam (right).

Since the mid-19th century, when bridge builders wanted beams of greater depth than the available rolled beams, they have turned to built-up beams (Figure 7). The technique of building up beams by riveting plates, angles, and channels had been used by the railroads prior to the Civil War, and riveting was the most common method of building up beams through the first half of the 20th century. With improvements in arc-welding, engineers increasingly turned to fabricated welded beams after WWII. These beams, in depths of up to 5' or more, became available in the early to mid 1950s, and were increasingly used during the 1960s, particularly with the availability of structural steel alloys developed specifically for welding. Bridge engineers made expanded use of welded beams citing material and fabrication savings over riveted built-up beams, which according to one 1960 study could weigh 25-30% more than similar welded beams for span lengths from 90' to 140'.[14]

Georgia was slow to use welded beams, in part because trained welders and fabricators were difficult to find in many areas of the state, and inspecting the quality of the welds required considerable experience or expensive testing equipment. The SHD did use welded cover plates to strengthen the flanges of I-beams beginning in the early 1950s and reported building its first “all-welded plate girder bridge” to carry SR 252

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[13] J. A. L. Waddell, Bridge Engineering, Vol. 1 (New York, 1916), pp. 410-411, 463-64. Waddell, one of America’s leading bridge engineers, wrote that the rolled beams were quickly becoming an important bridge-building material because of the above listed advantages.

[14] James G. Clark, ed. Comparative Bridge Designs (Cleveland: James F. Lincoln Arc Welding Foundation, 1954), pp. 24-40; Omer W. Blodgett, “Welded Plate Girders,” SASHO Proceedings (1960), pp. 32-35. Organizations such as the Lincoln Arc Welding Foundation in Cleveland and companies such as Westinghouse actively promoted the use of welding in steel construction. Many of the early advances in welded bridge construction occurred in northern states, including New York, Pennsylvania, Massachusetts, and Ohio.

over the Satilla River at Burnt Fort on the Charlton-Camden county line in 1956 (049-0038-0). Still the 1956 edition of the SHD's Specifications conservatively stated that "welding will not be permitted except where it is specified or to remedy minor defects where its use is approved by the engineers." In 1958, Charles Marmelstein reported that there had been an increase in the use of welding for shop and field work, and the bridge department was working to ensure that it was being done only by "qualified, tested" welders. It was not until the 1966 edition of the Specifications that the SHD dropped the restrictive language and greatly expanded its directions on the proper design, fabrication, and inspection of welded beams and connections. Much of the language was borrowed directly from national guidance issued by the American Welding Society.[15]

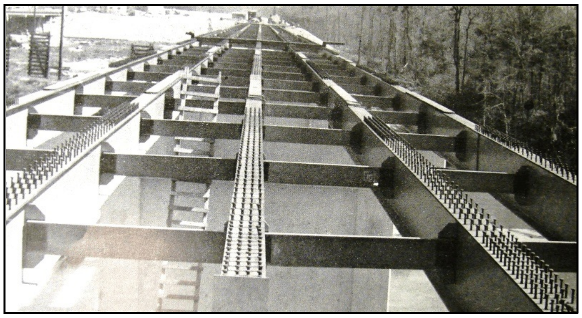

Figure 8. Construction photo showing shear stud connectors for composite beams prior to placing the concrete deck. Source: SHD, Biennial Report (1958).

Another refinement in steel stringer design was the use of composite, reinforced-concrete decks made by use of shear connections, usually metal studs (Figure 8) or spirals, set in the top flange of the steel stringers and embedded in the deck. The deck is thus mechanically attached to the steel beams and made to contribute to the load-resisting capacity of the superstructure with little additional cost and savings in steel by use of shallower beams. After WWII, American engineers began to make increasing use of composite decks based on a growing body of theoretical and empirical research that demonstrated their advantages. Georgia bridge engineers were interested in composite decks because of the cost savings and experimented with them from an early date. Doug Hudson recalls former state bridge engineer Searcy Slack (who continued to work in the state as a consulting engineer) and state bridge engineer Clarence Crocker investigating composite decks and coming up with a horseshoe-shaped, deformed-bar shear connection sometime in the early 1950s. The legs of the U-shaped connection were welded to the top of the beam and the curved end of the U bent up to grab hold of the slab deck. This connector was an "in-house" design because Crocker was concerned with infringing on shear connection patents, and it was a strict SHD policy not to pay patent royalties. The U-shaped connector was used for a few years before being replaced by commercially available spiral and stud connectors.[16]

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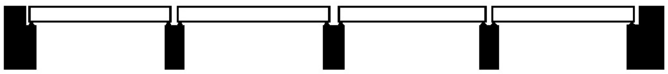
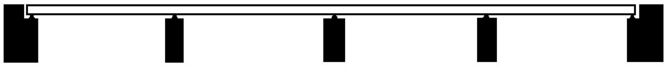
[15] SHD, Biennial Report (1955-56), p. 109, (1957-58), p. 107; Specifications (1956), pp, 389, 416; (1966), pp. 489-98.

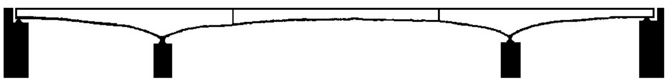
[16] Hudson (2007); Booker (1956), pp. 98-99. Non-composite construction is the traditional way of placing the reinforced concrete deck on the top flanges of the beams without mechanical connections.



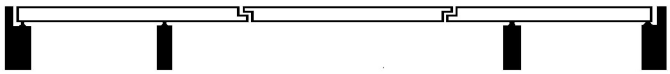
4-span simply supported



4-span continuous



3-span continuous-cantilever



3-span continuous-cantilever with drop-in section

Figure 9. Steel stringer designs.

Many of the multi-span steel stringer bridges in Georgia are continuous designs (Figure 9). Continuous designs are those where the beams continue uninterrupted over one or more piers. These bridges have significant economic advantages because they use less beam material for a given span length than simple supported (non-continuous) spans. Continuous spans distribute loads over two or more spans and thus can use smaller section beams than comparable simply supported spans, which must accommodate the entire load within each individual span. The reinforced concrete deck is also continuous, thus reducing the number of expansion joints, the failure of which is a primary source of bridge deterioration. Simple spans require expansion joints at the ends of each span.

The SHD built its first continuous steel stringer bridges in the late 1920s and early 1930s under the leadership of State Bridge Engineer Searcy B. Slack who was a pioneer in the development of standardized continuous-design bridges. Searcy Slack and Clarence Crocker developed a series of “short cuts” for designing continuous bridges, including using standardized units, such as the two-span 20'-20' and 27'-27' steel stringer bridges used during the 1930s and 1940s,, but it wasn’t until the department began using a computer to calculate continuous moments in 1957, that the advantages of multiple-span continuous designs could be realized to their fullest over a wide range of lengths, widths, skews, and superelevations.[17]

Contemporary with the application of continuous span technology was the use of the continuous-cantilever and drop-in section for longer span steel stringer bridges (usually those with main spans of about 65' to 90' long). These designs were also pioneered in Georgia by Slack in the late 1920s and early 1930s. The continuous-cantilever design typically has a drop-in (or suspended) section placed between two cantilevered sections or arms. The design allows for a longer clear span with a shallower beam, achieving economy not only in the depth of the beam, but also reducing the number of piers necessary to span a given length of crossing as compared to a simply supported span of the same beam depth. The connection between the cantilever arm and drop-in

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[17] Hudson (2007).

section is efficiently achieved by a pin-and-hanger connection, which also simplifies the stress calculations and is better suited to foundation conditions where uneven settlement is a possibility.[18]

The continuous-cantilever steel stringer design was based on engineering principles developed during the late 19th century for long-span cantilever truss bridges. In the late 1920s, bridge engineers first used the principles in combination with the newly available 30", 33" and 36"-deep, rolled wide-flange beams to build continuous-cantilever stringer bridges with spans up to about 100'. Previously, that length was usually spanned with truss bridges. The pin-and-hanger continued to be used in Georgia and elsewhere through the 1970s, but with the collapse of the Mianus River bridge in Connecticut in 1984 because of a failure in one of the pin-and-hanger assemblies, engineers all across the country, including those in Georgia, initiated a systematic program of eliminating or modifying this detail or relying on frequent inspections.

Another refinement common to many of Georgia's continuous steel stringer bridges is the use of high-strength bolts to make the connections at beam splice plates. Georgia's bridge engineers kept abreast of developments in high-strength bolts. The SHD revised its specifications in 1956 to allow for the substitution of high-strength bolts for rivets of equal size in any bridge project. High-strength bolts for bridge applications were developed beginning in the late 1930s and had by the 1960s become the dominant fastener used in steel bridge construction in the U.S., largely replacing hot-driven rivets. They represent an advance in the way connections were made in a variety of steel bridge types, including truss, girder-floorbeam, rigid frame, and continuous steel stringer. The use of high-strength bolts originated at university engineering labs in the late 1930s as a result of detailed investigations into the properties and behavior of fatigue and secondary stresses in steel connections. Based on the excellent results of these early scientific investigations, professional engineering and trade industry groups sponsored further trials and standardization of high-strength bolts for practical applications during the late 1940s and 1950s. High-strength bolts proved to have significant advantages over rivets from the standpoint of control of design and the economy of erection, especially eliminating the on-the-job labor costs associated with riveting. During the 1960s, high-strength bolts by and large supplanted rivets as the fastener of choice on most bridge projects.

A significant characteristic of a high-strength bolt is the ability to tighten the bolt to the desired stress and attain a precise amount of clamping force, thus giving the designer greater control over the properties and behavior of the connection detail. High-strength bolts are manufactured from medium carbon or alloy steels, usually having from 100-150% greater tensile strength than the mild-carbon steels typically used for common bolts. They also have short thread lengths that limit the elongation of the bolt under tension. Today, there are many types of high-strength bolts, but two of the most

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[18] Booker (1956), pp. 94-5.

common for bridge applications are the hex-headed bolts designated A325 and A490 by the American Society for Testing and Materials (ASTM). The medium-carbon steel A325 bolt was the first high-strength bolt to come into general use for bridge applications about 1951, and the A490, which is similar to the A325 except made from alloy steel for higher stresses and heavier loads, came into use about 1959.[19]

Steel Girder-Floorbeam Bridges

The steel girder-floorbeam bridge has been in use in Georgia since at least the late 19th century, but it was still in use through 1965 because it held some economic advantages, particularly the use of less steel as compared to steel stringer bridges in span ranges of about 90' to 150'. The history of the steel girder-floorbeam bridge type is similar to the steel stringer bridge type with the primary difference being that steel girder-floorbeam bridges consist of two or more longitudinal beams (i.e., girders) with transverse floorbeams supporting a deck. The longitudinal girders are typically built-up to achieve a greater depth than economically available from attainable rolled beam sections. The girder-floorbeam was developed in the late 1840s and first used by railroads. In fact, the girder-floorbeam was the only serious competitor to the metal truss for railroad applications during the 19th century. The technique of building up the girders has historically been riveting, an expensive and labor-intensive method. Welding became a more common alternative after 1945 with the advancement of welding technology and metallurgy to produce weldable, structural steel alloys. As with the steel stringer, Georgia was a relative late-comer nationally to welded designs and didn’t build welded girder-floorbeams until the late 1950s and 1960s. Some post-1930 girder-floorbeams also are continuous or continuous-cantilever designs with span lengths up to about 150'.[20]

Steel Truss Bridges

After 1930, the truss bridge technology, which had been the dominant technology for highway bridge building from the late 19th century to the early 20th century, largely fell from use in Georgia and throughout the nation. There were several factors related to the decline, including the development of reinforced-concrete bridge types and the availability of rolled beams in longer lengths, as well as the Depression of the 1930s when there had been very little new local bridge construction forcing most of the remaining truss fabricators to go out of business. This relegated the truss bridge type to a relatively narrow range of applications, mainly to longer span lengths between about 150' and 500' long where it still held some competitive advantages, especially if designed as a continuous structure. For this reason, the handful of truss bridges built

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[19] Kulak, Geoffrey L. and John W. Fisher and John H. A. Struik. Guide to Design Criteria for Bolted and Riveted Joints. 2nd Ed. (New York: John Wiley & Sons, 1987), pp. 1-4; SHD, Specifications (1956), p. 385.

[20] Carl W. Condit, American Building, 2nd ed. (Chicago: University of Chicago Press, 1982), pp. 225-226.

Figure 10. SR 53 over Lake Lanier, built in 1956. Source: Dixie Contractor (1956).

in Georgia from 1955 to 1965 tend to be long-span bridges and include the three truss bridges built over the U.S. Army Corp of Engineer's 1955-56 Lake Lanier flood-control project on the Chattahoochee River near Gainesville (Figure 10). These bridges required very high piers (over 100' high) because of the depth of the reservoir. The economy of the long-span trusses was based on reducing the number of piers so to save substantially on the cost of substructure work.[21]

Reinforced-Concrete Bridges

Concrete is a mixture of stone aggregate, sand, and cement that when mixed wet can be cast into a variety of shapes. As concrete cures, it undergoes a chemical process, and once set forms a very hard, durable, low-maintenance material. A structural weakness of concrete on its own is that it has low tensile strength. To overcome this, steel bars, which have high tensile strength, are placed in the tension zones. The concrete actually bonds with the steel bars forming its own distinct composite material, known as reinforced concrete.

Reinforced concrete emerged as an important bridge-building material in the 1890s and 1900s, and it had become a standardized and widely available material by the 1910s. The two most common reinforced-concrete bridge types – T beam and slab – were among the first standards developed by the SHD in the late 1910s, and they continued with refinements to be among the most common standardized bridge types constructed through the 1960s. Reinforced-concrete bridges are numerous in Georgia, and account for over 1,700 of the nearly 4,000 extant highway bridges dating to before 1966.

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[21] "C. Y. Thomason Speeds Work on Buford Reservoir Project," Dixie Contractor (Jan. 19, 1955), pp. 18-20, 82; "Steel Rising on Bolling Bridge in Buford Reservoir Area," Dixie Contractor (Mar. 21, 1956), pp. 22-23. The three truss bridges over Lake Lanier are: (1) Browns Bridge Road over Lake Lanier, Forsyth County (117-0022-0), 5 spans, 1,372'-long; (2) SR 53 Westbound over Lake Lanier, Hall County (139-0020-0), 4 spans, 1,216'-long; (3) Bolling Bridge over Lake Lanier, Forsyth County (117-0010-0), 3 spans, 800'-long.

The basics of reinforced-concrete bridge technology changed very little after 1920, although, as with steel, scientific advances and instrumentation resulted in a better understanding and control over the material's physical and chemical properties. Georgia bridge engineers and contractors benefitted from the development of new high-strength, lightweight concretes; from retarding agents that when added to concrete allowed it to be trucked over longer distances; and from centralized mixing plants and electronic instrumentation to better ensure the quality and uniformity of the mix. Reinforced concrete is a very economical, low-cost, high-strength material that is easily standardized and continued to be used through 1965.

T Beam Bridges

T beam bridges are composed of cast-in-place reinforced concrete beams with integral monolithic flanking deck sections used for spans of usually 25' to 65' in length. The primary reinforcing steel is placed longitudinally in the bottom of the beam stem, and the deck or flange reinforcing is placed perpendicularly to the stem (Figure 11). T beams were favored by many state highway departments because of their low long-term maintenance and overall economy of material. The T beam is based on the integral connection of the longitudinal beam and deck section proportioned to achieve a light, strong, and economical section. The SHD adopted standard plans for T beam bridges as early as 1917, and it was a workhorse bridge type in the development of the Georgia State Highway System from the 1920s to 1960s. Georgia currently has approximately 1,080 T beam bridges dating from the early 1900s to 1965. There were

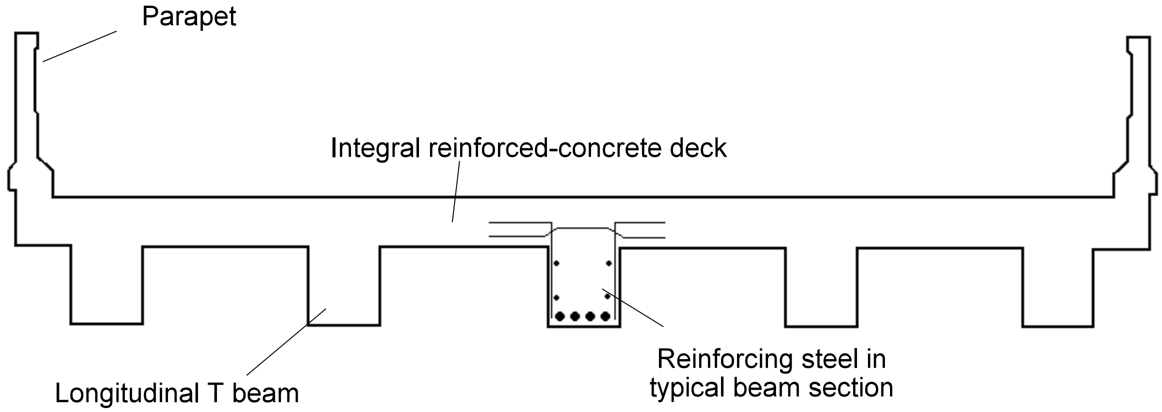

Figure 11. Typical T beam bridge cross section.

few significant changes in the technology after 1920 and later examples are for the most part individually undistinguished and standardized.[22]

Some multi-span T beam bridges from the mid 20th century are continuous designs for reasons of savings in material and elimination of deck joints. The SHD's first long-span continuous-design T beam bridge was built in 1943 to access the Bell Bomber Plant in Marietta, Cobb County (James Jackson Parkway over the Chattahoochee River, 121-0116-0). The impressive, 15-span, T beam bridge with haunched beams was designed by Clarence Crocker and ranks as one of the most significant mid-20th-century bridges in the greater Atlanta area. Continuous T beam bridges use less material than simple-span T beam bridges of comparable lengths, but more importantly offered an alternative to steel bridges, a consideration during the war and into the 1950s due to the military's demand for steel and periodic steel shortages. The haunched continuous designs were, however, difficult to standardize, and even more difficult to design at varying skews and lengths. According to Doug Hudson, almost all of the T beam bridges built in Georgia were simple spans.

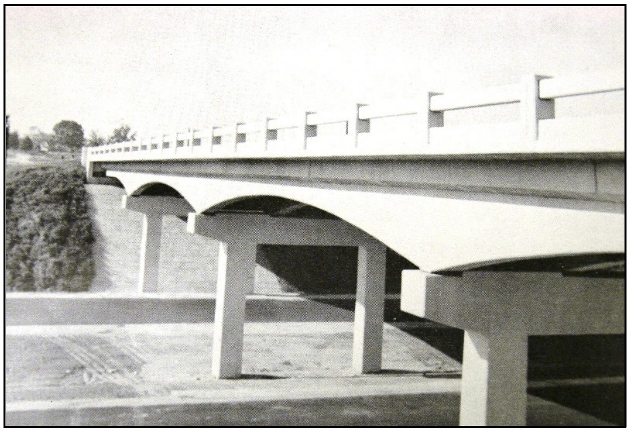

Figure 12. Typical continuous-design T beam bridge. SR 316 over I-85 in Gwinnett County. Source: SHD, Biennial Report (1958).

In 1956, the SHD bridge division did make an attempt to see if continuous T beam designs would be economical for use as a standard overpass type on the interstate system (Figure 12). Lyman Bradley, the BPR regional bridge engineer, reported that Alabama was using the continuous designs at about two-thirds the cost of simple T beam bridges. Alabama's state bridge engineer, John Chambers, gave a presentation on his state's success with the bridges at the annual Southeastern Association of State Highway Officials (SASHO) meeting, which was held in Atlanta in September 1956. In response to the BPR request and Alabama's successful experience, the SHD designed four of the continuous T beam bridges for the I-75 project in Tifton, and, as predicted, the bids came in significantly lower than for a conventional T beam bridge of the same overall length. The contractor, however, "lost his shirt" because he had not factored in the expense of the extra formwork, which had to be set on a firm foundation to prevent settlement, formed to the curve of the beams, and run the entire length of the bridge

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[22] T beam bridges are standard fare in most period engineering textbooks. See, for example, Leonard A. Church and Charles Edward O'Rourke, Design of Concrete Structures 2nd ed. (New York: McGraw-Hill: 1926): pp. 105-117; George A. Hool, Reinforced Concrete Construction. Volume III. Bridges and Culverts, 2nd ed. (New York: McGraw-Hill: 1928), pp. 409-413. Numerous statewide bridge surveys and a cursory glance at nationwide NBIS data confirms the ubiquity of the T beam bridge type.

from end to end. Over the next nine months, word got around to other Georgia contractors, and the continuous T beam went from being the cheapest to the most expensive bridge that could be built. The conservative nature of Georgia bridge-building practices shown through.[23]

Reinforced-Concrete Slab Bridges

The reinforced-concrete slab bridge is another very common, early 20th century standardized bridge type that continued to be used through 1965. Georgia has more than 380 precast and cast-in-place examples dating from 1955 to 1965. Slab bridges were used for spans under about 35' long. The bridge type concentrates reinforcing steel in the lower portion and ends where tensile forces and shear are the greatest (Figure 13). The amount of steel and depth of the slab is predicated on length and live-load requirements. Slab bridge technology developed along with other reinforced concrete bridge types, such as the arch and T beam, in the late 19th century and matured during the first decade of the 20th century. Advancement in the understanding of reinforcing placement to accommodate tension and shear forces resulted in reinforced concrete slab bridges becoming one of the favored bridge types for short-span bridges. The slab bridge type proved well suited to the preparation of standard drawings with the result that the nation's state highway departments built literally thousands of nearly identical examples.

Many of Georgia's post-WWII slab bridges are precast rather than cast-in-place as was most common prior to 1941. Precast slab bridges are composed of panels, usually up to about 20' long and between 4' and 5' wide, that were fabricated in casting yards, transported to bridge sites, hoisted into position by crane, and then joined by transverse tie rods and grouting placed between the panels. The standard precast slab

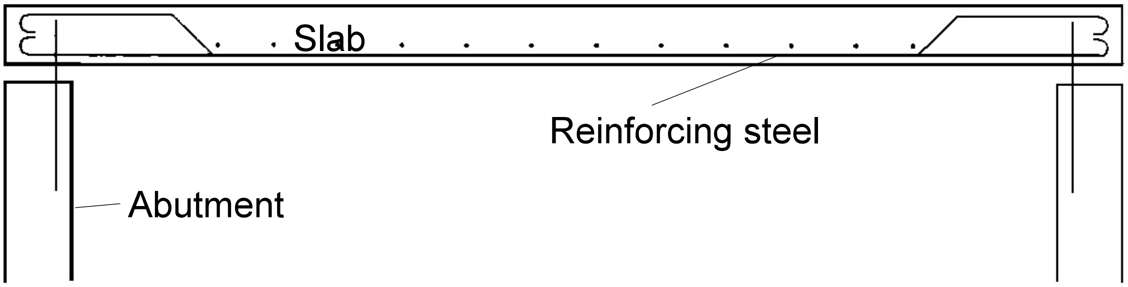

Figure 13. Typical reinforced-concrete slab bridge.

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[23] Hudson (2007); John Chambers, "Design and Construction of Long-Span Concrete Bridges," SASHO Proceedings (1956), pp. 112-15.

bridges used in Georgia beginning in the late 1940s were developed by state engineers specifically to address the pressing need for an economical, speedily erected, relatively lightweight, and low-maintenance bridge for H15 live loads on low-volume rural roads. With increased federal and state aid earmarked for rural roads improvement, the slab bridges were seen as an ideal solution to replacing the many wood-decked stringer and truss bridges that had been typical of most county bridge work prior to WWII. Precasting had the advantages of savings in forms and falsework, elimination of on-the-job labor, speed of construction, better maintenance of traffic flow, and closer quality control of concrete. The standard precast designs also reduced the number of engineering man-hours required for relatively routine design work. By the mid-1950s, a number of companies, including the Albany Concrete Products Company and the Link-Belt Company (Atlanta), were supplying a large number of precast units to the SHD and county road commissions based on standard plans developed by state bridge engineers.[24]

Figure 14. "Harry Brown" type, precast slab bridge. Source: Georgia Highway Proceedings (1957).

Early significant examples of precast designs that were developed for Georgia's rural roads programs were identified by the previous study of Georgia's pre-1955 bridges. These included the flat-panel design with the 1'-wide cast-in-place shear keys in the space between the panels and the "Harry Brown type", adopted as a state standard in 1952 with its distinctive, chamfered, 2'-high, concrete curbs designed to withstand impact (Figure 14). The available primary and secondary literature has identified no significant post-1955 variations on the precast slab designs. This will be confirmed during the GDOT bridge inspection file review.

Channel Beam Bridges

A channel beam bridge, or waffle slab as it is better known in Georgia, is a precast bridge composed of units that are C-shaped (also known as inverted U-shape) in cross section (Figure 15). The beams are typically 20' to 35' in length and 3' to 4' wide, and can be either reinforced concrete or prestressed concrete (after 1956). The individual beams are locked into a unit by grouted keyways and lag bolts through the beam toes. The channels have diaphragms giving them a waffle-like appearance. There is no visual difference between reinforced concrete and prestressed concrete channel beams, so plan sheets need to be consulted to accurately determine the material.

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[24] SHD, Biennial Report (1955-56), pp. 105-06; C. W. Leftwich, "Road and Bridge Maintenance Problems," Georgia Highway Proceedings (1955), pp. 53-56; J. Roy Fraser, "Precasting Small Concrete Bridges," Georgia Highway Proceedings (1957), pp. 27-43.

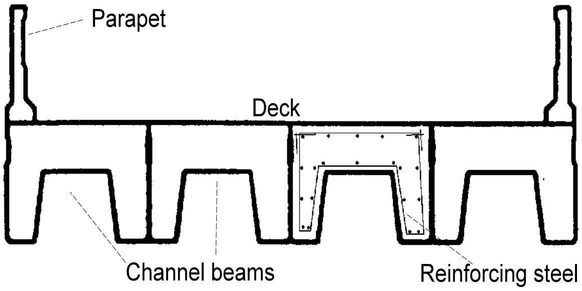

Figure 15. Cross section of typical channel beam bridge.

Channel beam bridges were known in the late 1910s and were one of the SHD's early standardized bridge designs, but no pre-1945 examples are known to survive in Georgia. The channel beam had a resurgence after WWII as one of the precast types promoted as an economical alternative for improving rural bridges. It had the advantage of providing a longer, lighter-weight beam than the precast flat slabs, which were generally limited to spans of less than 20'.

Prestressed-Concrete Bridges

The introduction of prestressed concrete as a bridge-building material was one of the most significant technological advances in America during the 1950s, but Georgia was at the periphery of this development and never a major player. Georgia's bridge engineers, while well aware of prestressed concrete, did not go out of their way to promote its use and based their standard beam designs directly on those proven to be successful and economical in other states. As the price of steel crept upwards during the 1960s, prestressed concrete gradually became more competitive but it did not become the dominant material that it is today in Georgia until the mid 1970s. Prestressed-concrete bridges played an important role in efforts to accelerate the completion and reconstruction of the interstate highways, especially those in metro Atlanta in the 1980s.

Prestressed-concrete beams are internally stressed in compression, usually by high-strength steel wires or cables, to counterbalance the stresses from bending caused by external loads. One of the primary advantages of prestressed concrete is that the designer can make the compressive forces induced into the beam equal to the stresses expected from the dead and live loads and thus counteract the tendency of concrete to develop flexure cracks (vertical cracks that usually start in concrete beams in areas where the bending caused by loads is the greatest). Less deflection also extend the life of the deck. Prestressed concrete is a highly economical use of material that results in strong beams that are lightweight in comparison to conventional reinforced concrete. The beams can be a variety of shapes including "T", channel, slab, voided box, and "I". Nationally, the box and "I" beams were the most common beams used during the mid 1950s through the 1960s, but the SHD only made use of the "I". Prestressed concrete also proved to be a strong, economical material for substructure piling. During the late 1950s, prestressed concrete piles became the preferred alternative to steel and timber piles in Georgia.

Prestressed-concrete beams are made by either pretensioning or post-tensioning. In pretensioning, the steel is positioned, stretched to develop the required stress, and then held in place while the concrete is placed in the forms. After the concrete has cured, the tension in the steel is released and the load is transferred to the concrete. In post-tensioning, the steel is positioned in the unstressed condition in conduits or sleeves and the concrete placed around the sleeves so that the steel is not in contact. After the concrete cures, the steel wire, which is anchored at one end, is stretched by jacking to achieve the required stress, locked in place, and the force transferred to the hardened concrete using anchorages or end blocks. Grout is then injected into the conduits or sleeves.

Prestressed concrete first appeared in bridge applications in Europe during the first decades of the 20th century. Its most noted developer was Eugene Freyssinet of France. Prestressed concrete was slow to spread to the United States, but eventually found its first application in water tanks before World War II. Philadelphia's 1949-51 Walnut Lane Bridge inaugurated the modern prestressed-concrete bridge era. The bridge had 160'-long beams that were cast on site and then post-tensioned. The progress of the Walnut Lane Bridge was followed closely by engineering journals and magazines with the result that many consultant engineers and private concrete-casting companies began to experiment with and develop prestressed-concrete bridge applications. After 1951, many firms entered the field marketing a variety of shaped beams. By the late 1950s, standardized prestressed-concrete beams were in used in many states for spans up to about 80', and the nation's leading prestressed-concrete bridge engineers were moving on to new challenges in long-span and continuous-design prestressed-concrete bridges.[25]

Georgia's bridge engineers demonstrated an interest in prestressed concrete but did not rush forward to experiment with it. The primary forums through which SHD engineers learned about and discussed the prospects of prestressed concrete were professional conferences and meetings, like the annual conferences of AASHO and the Southeastern Association of State Highway Officials (SASHO). SASHO's bridge committee almost always had a paper or session on prestressed concrete at annual conferences from 1954 to 1965. In February 1956, William Dean, Florida's state bridge engineer and a national leader in the development of prestressed concrete, spoke at the Annual Georgia Highway Conference at Georgia Tech, concluding in front of the assembled Georgia engineers, contractors, faculty, and students that prestressing had progressed from "an interesting possibility" to a "firmly established construction practice," although Georgia's SHD had yet to build its first prestressed-concrete bridge.[26]

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[25] "Recent Developments in Prestressed Concrete," SASHO Proceedings (1960), pp. 42-43.

[26] W. E. Dean, "Comparative Costs of Prestressed Construction and Conventional Types in Trestle Spans of Florida Bridges," Georgia Highway Proceedings (1956), pp. 10-15.

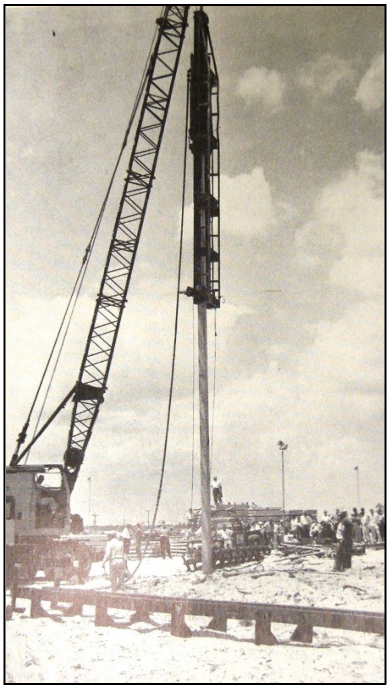

Figure 16. Engineers and contractors gather to watch the driving of a prestressed-concrete pile. The lightweight and strong piles were more easily handled than reinforced-concrete piles. Source: Georgia Highway Proceedings (1957).

In Georgia, the first successful uses of prestressed concrete were not for bridges but for building roof systems. The Albany Concrete Products Company was the state's pioneer developer of prestressed concrete units with most of its early work prior to 1955 involving fabrication of channel and T-section roof panels for low-cost federal housing projects in Atlanta and Columbus. One of the company's largest projects was the roof for the 1956 Singer Sewing Machine Company Warehouse in Atlanta.[27]

While some Georgia architects and builders were eagerly exploring the possibilities of prestressed concrete, Georgia's bridge engineers were more cautious. The first successful use of prestressed concrete in Georgia bridges was for substructure piling (Figure 16). Prestressed-concrete piles offered a lighter weight and stronger alternative to reinforced-concrete piles, which had been used in Georgia since at least the 1920s. The SHD prepared its first standard plans for prestressed concrete piles in 1956. The largest in-state fabricator was the Macon Prestressed Concrete Company, which began operations in early 1956 and was producing in excess of 4,000 linear feet of piles per month by late 1958. Although Macon Prestressed Concrete aspired to do more work for the SHD, its most successful product was prestressed-concrete double-T roof systems.[28]

Contemporaneous with the construction of the 1949-51 Walnut Lane Bridge, several state highway departments, including Pennsylvania's and Florida's, were developing pretensioned, prestressed-concrete beams for use as standard bridge types on their state highway systems with encouragement from the federal BPR and AASHO. Chief federal bridge engineer Eric L. Erickson believed that prestressed concrete could play an important role in standardized bridge construction. BPR, in cooperation with the Prestressed Concrete Institute (PCI), published its first edition of the influential Design Criteria for Prestressed Concrete Bridges in 1954 and a second greatly expanded edition with standard plans in 1956. Among the first places nationally that these types of standardized beams were used was New Jersey's Garden State Parkway in 1953-54.

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[27] "One Answer to New Trends in Concrete Design Usages by Albany, Ga., Firm," Dixie Contractor (May 25, 1955), p. 16; "Prestressed Construction Used on New Singer Building," Dixie Contractor (July 25, 1956), pp. 8-9.

[28] Paul Jones, Jr. "Production and Placing of Prestressed Tee Slabs and Piling," Georgia Highway Proceedings (1959), pp. 57-61.

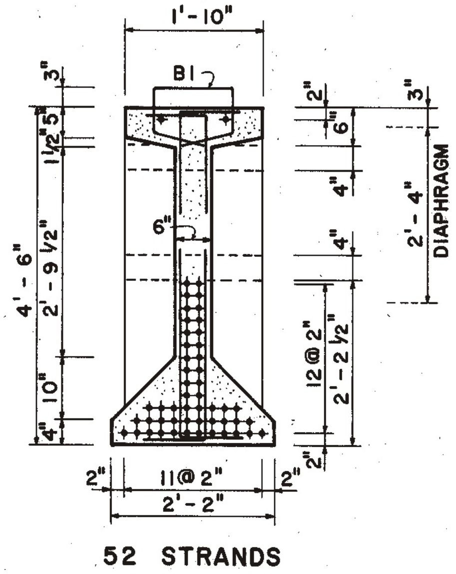

Figure 17. Cross section of BPR-designed prestressed-concrete beam, 1954. Georgia's early beams were based on the BPR's work. Source: Nasser (1979).

Following this, many state highway departments, including Georgia's, began to use the standard AASHO prestressed concrete beams.[29]

Charles Marmelstein reported that the SHD was preparing standard drawings to conform with the BPR design criteria in early 1957, but cautiously concluded that "the economy of this construction in Georgia is yet to be determined." While willing to explore the possibilities, Marmelstein and the SHD were not convinced that prestressed concrete would be cost competitive with other bridge types. In 1957, the bridge division prepared standard plans for prestressed concrete beams of 40', 42', 48', 56', 60', and 64' long. In 1960, standard beams of 70' and 78' long were added. Over the next several years based on experience and analysis of such factors as creep and shrinkage of concrete and relaxation of stress, AASHO's specifications for prestressed concrete bridges became increasingly detailed about such requirements as minimum cover, spacing of prestressing steel, design of end blocks, allowable stresses, and embedment of prestressed strands. The AASHO specifications were incorporated into the SHD's plans.[30]

Charles Marmelstein assigned one of his young engineers, Otis Gillabeau, who had some introduction to prestressed concrete in college, to design the first prestressed concrete beams starting in late 1956. The first six bridges were let to contract in March 1957 on a stretch of I-85 in DeKalb and Gwinnett counties. Vernon W. Smith, Jr. was the senior resident highway engineer assigned to supervise the beam fabrication. The beams, which ranged from 42' to 80' long, were fabricated by Prestressed Concrete of Georgia, located in College Park (Figure 18). Contractor for the bridge erection was the Wainer Construction Company of Valdosta. Fabrication of the beams began in June 1957 and the first three bridges were 90% complete in February 1958. Two of these

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[29] FHWA, America's Highways (1976), p. 433; George D. Nasser, ed., Reflections on the Beginnings of Prestressed Concrete in America (Chicago: Prestressed Concrete Institute), 1981. States out in front on prestressed concrete included Pennsylvania, Florida, Tennessee, and Colorado. See also, Howard Newlon, Jr., "Prestressed Concrete," in Thomas C. Jester, ed., Twentieth-Century Building Materials: History and Conversation (New York: McGraw-Hill), 1995, pp. 115-17; C. A. Marmelstein, "Prestressed Concrete," Georgia Highway Proceedings (1957), pp. 23-26.

[30] Nasser, pp. 319-25; AASHO, Standard Specifications (1957, 1961, 1965); Standard Bridge Plans, undated manuscript in the GDOT Plan Room, Atlanta.

bridges are still in place although widened in 1986 (I-85 over Sweetwater Creek 135-0052-0/135-0053-0).

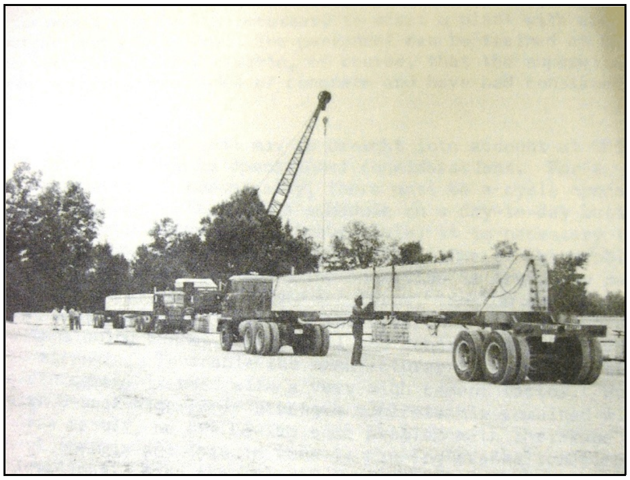

Figure 18. A prestressed-concrete beam is loaded at the College Park fabricating yard for transport to the bridge site on I-85. Source: SHD Biennial Report (1958).

Smith reported on the SHD's field experience with prestressed concrete at the Annual Georgia Highway Conference in 1958. Although he was willing to conclude that "prestressed concrete is a good bridge construction medium," he also noted that unanticipated problems and additional costs had made the SHD's first experience with prestressed concrete disappointing in many ways. The SHD lab had no experience testing high-tensile strength tendons and after much research and several failures eventually was able to devise acceptable methods. The first beams developed horizontal cracks in the end blocks, necessitating a revision in plans for additional reinforcing bars. A major problem was controlling the curing of the beams, requiring cool water trickling on the beams in hot summer weather, and steam curing in cold winter weather with constant monitoring to ensure no quick fluctuations in temperature that would damage the beams. Some beams were post-tensioned, rather than pre-tensioned, and these encountered problems due to friction and binding of the tendons, and even the loss of several of the expensive tendons due to overstress damage. Another significant factor in increasing the cost of the prestressed-concrete bridges was the requirement of special expansion-end bearing plates of bronze, which were high-priced and easily damaged. As a result, the SHD lab began investigations into neoprene (rubber-like) bearing plates.[31]

From June 1957 to June 1959, the SHD reported letting to contract 41 prestressed-concrete stringer bridges because of the slow delivery of steel beams. Most of the prestressed-concrete bridges were built on the interstate highway system with encouragement from the BPR to advance construction as quickly as possible. In addition to 14 prestressed concrete bridges on I-85 between Atlanta and the South Carolina line (Figure 19), another 11 were placed on I-75 near Tifton. A number of these bridges are extant.[32] One of the reasons for these projects was that the SHD

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[31] V. W. Smith, Jr., "Plant and Field Experience with Prestressed Concrete," Georgia Highway Proceedings (1958), pp. 112-19.

[32] Extant examples in Tifton County include Adcock Road over I-75 (277-0025-0), Omega-Eldorado Road over I-75 (277-0067-0), and Oak Ridge Road over I-75 (277-0020-0).

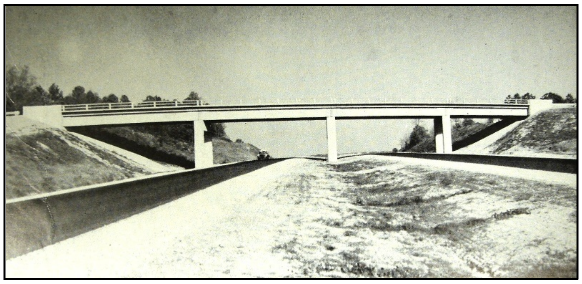

Figure 19. One of the SHD's first prestressed-concrete stringer bridges on I-85 in Gwinnett County. Source: SHD, Biennial Report (1958).

wanted to determine if prestressed concrete beams could be delivered more quickly and at less cost than steel beams, which could take up to two years to be delivered and that was not acceptable for accelerated interstate construction. Building bridges quickly and efficiently was one of the keys to progressing interstate projects since grading and roadway work could not be easily completed without them.[33]

The prestressed-concrete bridges, however, tended to come in about 10% higher in price than the alternative steel or reinforced-concrete designs, which dampened enthusiasm for the new material in Georgia. The time savings did not turn out to be as great as had been hoped because of continued inefficiency and quality-control problems in Geogia casting yards. In about 1960, for example, the bridge division approached Macon Prestressed Concrete's Vice President Paul Jones about supplying beams for a series of long overflow bridges on I-16 coming out of Savannah. The thought was that per unit cost of beams might come down on such a large project. Macon Prestressed Concrete's estimate still came in higher than expected, and the SHD lost interest. Macon and the other prestressed concrete fabricators in Georgia reportedly lacked the capital to invest in the equipment, space, and experienced personnel that might have made large-scale operations more efficient and thus less expensive.[34]

Prestressed-Concrete Bridges on County Roads

There is little evidence that Georgia counties were any more progressive than the SHD in the early use and application of prestressed concrete. A few county commissions appear to have been receptive, but most were not. Of the approximately 90 pre-1966 prestressed concrete bridges in the study population only 26 are county-owned bridges. Spalding County has 18 of the 26 bridges dating from 1956 to 1959. They are classified as prestressed-concrete slab bridges with 20'-long spans. The Troup County road commissioners reported that they began using a standard prestressed-concrete channel beam bridge in 1962, and four examples dating to 1965 are in the study population.[35]

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[33] Erickson (1956), pp. 101-07.

[34] SHD, Biennial Report (1957-58), p. 108; Hudson (2007); Jones (1959), pp. 57-61.

[35] Earl Edwards, "Troup County Finds "Free" Labor Best," Georgia County Government Magazine (Oct. 1962), pp. 11-13.

Timber Bridges

Wood's primary advantages as a bridge material are its natural abundance and its ability to be acquired and worked with but a few simple tools. Its inherent disadvantages are susceptibility to natural deterioration from fungi, insects, and moisture; high maintenance requirements; lack of resistance to fire; and strength properties, which depend on the species of tree but generally limit its effective use to bridges carrying, by modern standards, relatively lightweight loads over short spans. The shortcomings of timber bridges were among the primary impetuses to the development of iron bridges for railroad usage during the 19th century, and timber bridges also became less desirable for use on highways with increased motor vehicle usage during the 20th century. Nonetheless, they have continued to be built primarily for reasons of economy, although usage has been mostly relegated to low-volume roads in sparsely developed settings. As of 2007, GDOT's bridge inventory reported more than 150 timber bridges in use, mostly on county roads. These bridges typically are short-span bridges (less than 20' long) and less than 30 years old, reflecting the fact that timber bridges, due to the nature of the material, have relatively short life cycles. The study population includes 11 timber stringer bridges built from 1955 through 1965 that are part of the continuum of timber bridge building in Georgia. Although the SHD did not have standard timber stringer bridge plans, it did require that the wood be graded and selected according to the Southern Pine Association's rules and specifications.[36]

Movable Bridges

The 1955-65 study population includes one bascule bridge – the 1963 Island Expressway over the Savannah River in Chatham County (051-0132-0). Further context for this bridge will be developed following a review of bridge plans and files at GDOT. After WWII, the SHD made a concerted effort to replace movable bridges with high-level, fixed-span bridges that would provide adequate vertical clearance to navigation and eliminate delays to traffic. As well, movable spans were expensive to operate and maintain.

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[36] SHD, Specifications (1966), p. 511.