

# McCurdy Road Stress-Laminated Timber Bridge

## A Viable Option for Short-Span Design

James A. Kainz, Forest Products Laboratory, USDA Forest Service  
Charles A. Hill, Richland County, Ohio

### Abstract

The McCurdy Road bridge is a 4.9-m- (16-ft-) long and 7.9-m- (26-ft-) wide single-span, stress-laminated deck superstructure, pressure treated with ammoniacal copper quat (ACQ) preservative. The bridge was constructed in June 1995 as the most economical replacement structure when compared with several alternative short-span designs. Results of this case study indicate that a stress-laminated timber bridge is a structurally and economically viable option for 3.1- to 6.1-m (10- to 20-ft) crossings. Future stress-laminated timber bridges in Richland County will be improved by utilizing lessons learned from the design, construction, and performance monitoring of the McCurdy Road bridge.

Keywords: Timber, bridge, stress laminated, preservative, economics.

### Introduction

The United States is experiencing an infrastructure dilemma in which approximately 50 percent of all inspected bridges have been deemed structurally deficient or functionally obsolete. All states have adopted annual inspection programs to identify and rank bridges. The seriously deficient bridges are rehabilitated or replaced as necessary, while others are maintained as best as possible with available funds.

Short-span bridge replacements are a significant problem in the maintenance of local highway infrastructure. These bridges are defined as structures with total lengths between 3.1 to 6.1 m (10 to 20 ft) and may include multiple culvert crossings. Long-span bridges receive a greater portion of the available highway funds for repair and replacement. Therefore, the remaining short-span bridges in a local government inventory become a significant drain on the highway maintenance budget. However, all bridges must be maintained at the same minimum level because any bridge failure, long or short span, can lead to either road closure and/or personal injury.

The economics of short-span bridge maintenance are adversely impacted by Federal and State rules which, in most cases, exclude these bridges from cooperative programs intended to aid local agencies in their bridge replacement plans. Most cooperative programs require bridges to be at least 6.1 m (20 ft) long, which excludes most short-span bridges. This places the responsibility for design, construction, maintenance, and repair of these bridges on local governments.

A typical example of the impact of short-span bridges on the highway budget can be found in Richland County, Ohio. In this county, the bridge inventory numbers 361 bridges, of which 149 (41 percent) are considered short span. In this day of decreasing budgetary dollars, Richland County is forced to maintain nearly half their bridges without support from State and/or Federal funds.

One such short-span crossing in Richland County is the McCurdy Road bridge. This paper describes the development, design, economics, and construction of the McCurdy Road timber bridge. This single-span, stress-laminated timber bridge fulfilled Richland County's need for a low-cost, short-span replacement bridge.

### Background

The McCurdy Road timber bridge is located in the southeastern part of Richland County, Ohio, approximately 0.4 km (0.25 mile) south of State Highway 97 on McCurdy Road (Fig. 1). This bridge spans a branch of the Babble Brook, which is a tributary of the Mohican River. The original crossing was a concrete box culvert built in the late 1930s (Fig. 2). After many years of use, this culvert was severely deteriorated, resulting in exposed steel and crumbling concrete. The bridge was posted with a 5.4-tonne (6-ton) load limit that restricted the crossing of heavy vehicles, which included fire equipment. Emergencies south of the bridge required a 9.7- to 12.9-km (6- to 8-mile) detour via Ashland County, which is located east of Richland County. In addition to the load restrictions, the cost of structure maintenance had increased beyond efficient means to maintain minimum traffic. Under the Ohio Department of Transportation (ODOT) condition grading system, this bridge was rated code 2 in 1993 (ODOT 1995). A code two designation is one step away from structure closure. (Code 1 represents structure closure.) Therefore, the McCurdy Road bridge was readied for replacement.

In examining possible replacement bridge types for the McCurdy Road bridge, considerations were made regarding economics because of limited funds. In addition, aesthetics were considered due to increased recreational activities in the area. Three alternative bridge designs were examined. The designs included three- and four-sided concrete culverts, corrugated metal arch pipe, and a stress-laminated timber bridge. In evaluating each design, several factors were examined: ease of construction, cost of construction, expected life of the structure, maintenance costs, and overall life of structure costs. All three designs adequately fulfilled the aesthetic requirement.

### Concrete Culvert

A box culvert is considered a viable option for spans under 6.1 m (20 ft). In this case, three- and four-sided culverts were considered. The four-sided culvert was quickly eliminated, because the required size was not readily available. Special ordering would have increased the cost to prohibitive levels. A three-sided box culvert was available in the standard sizes required for

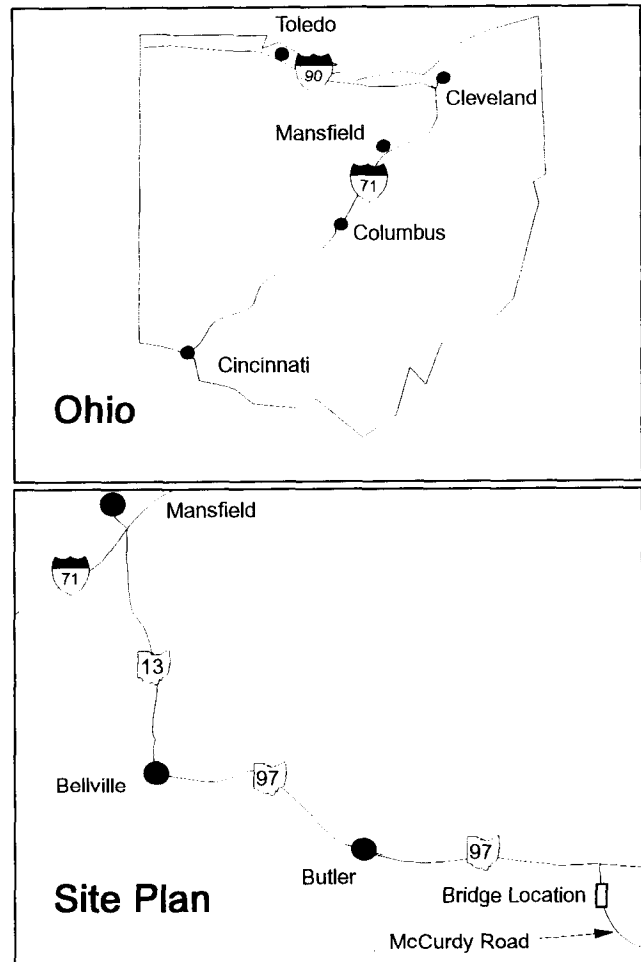


Figure 1—Location of the McCurdy Road bridge.



Figure 2—Original McCurdy Road crossing in 1986.

this project. A spread footing and a pile foundation were considered as options, depending on the geotechnical examination.

The construction costs (discussed later) for the three-sided culvert with a spread footing were similar to the timber bridge option. However, long-term service life and maintenance cost estimates were not reliable, because long-term performance data are not available on these type of structures. As a result of the uncertainty of costs, this option was not selected.

### **Corrugated Metal Arch Pipe**

The second option examined was the use of two 2.3-m- (90-in-) diameter corrugated metal arch pipes. This option was considered to be very economical during the construction phase of the project, because the material is relatively inexpensive and installation requires only light-duty equipment. However, this type of design requires increased maintenance costs over time and would have required complete replacement during the life cycle of the other crossings examined. Therefore, this option was not chosen.

### **Stress-Laminated Timber Bridge**

A stress-laminated timber bridge was also examined as an option for bridge replacement. This type of bridge consists of a longitudinal deck superstructure, installed on timber pile abutments using timber backing boards and wing walls. This bridge was the most economical of the three types of designs examined. It also allowed the county to complete the installation in-house, because only light-duty equipment is required for construction.

After reviewing the three bridge options presented, Richland County personnel determined that a stress-laminated timber bridge would be an ideal bridge replacement. However, Richland County was unfamiliar with the design and construction of modern timber bridges; therefore, they applied for assistance from the Timber Bridge Information and Resource Center (TBIRC), which is part of the USDA Forest Service. With funds designated under the Timber Bridge Initiative (TBI), the TBIRC granted a portion of the total bridge cost to Richland County. Thus, the McCurdy Road bridge was included in the Forest Service timber bridge program.

### **Objective**

The objective of this study was to examine the McCurdy Road timber bridge as a viable, low cost bridge replacement product. In addition, the economics of short-span timber bridge construction are examined.

## **Design, Economics, and Construction**

The design and construction of the McCurdy Road timber bridge were a cooperative effort involving several organizations and individuals. The following presents an overview of the design, economics, and construction of the completed timber bridge.

### **Design**

Design of the McCurdy Road bridge was completed by a consulting engineer retained by Richland County. Aside from those design aspects related to stress laminating, the bridge design was in accordance with the American Association of State Highway and Transportation Officials (AASHTO) *Standard Specifications for Highway Bridges* (AASHTO 1992) for two lanes of AASHTO HS20-44 truck loading. Design criteria for stress laminating were based on the *AASHTO Guide Specifications for the Design of Stress Laminated Wood Decks* (AASHTO 1991).

The design geometry of the McCurdy Road bridge provided for a single-span, simply supported structure, 4.9 m (16 ft) long, 7.9 m (26 ft) wide, and 254 mm (10 in.) deep (Fig. 3). The stress-laminated deck consists of full-length, 51-mm (nominal 2-in.) Southern Pine lumber. Butt joints were not necessary in this deck because of the relatively short span.

Design values for the Southern Pine laminations were based on the *National Design Specification for Wood Construction* (AFPA 1991) for lumber visually graded No. 2 in accordance with Southern Pine Inspection Bureau rules (SPIB 1991). The tabulated design values for the Southern Pine species combination were 7,240 kPa (1,050 lb/in<sup>2</sup>) for bending strength, 11,030 MPa (1,600,000 lb/in<sup>2</sup>) for modulus of elasticity (MOE), 620 kPa (90 lb/in<sup>2</sup>) for shear strength, and 3,900 kPa (565 lb/in<sup>2</sup>) for compression strength perpendicular to grain. All design values were adjusted with the appropriate wet-use factors, and laminations were specified to be at or below 19 percent moisture content prior to preservative treatment and bridge installation.

The stressing system consisted of six high strength steel bars, which were inserted through predrilled holes at the center of the laminations. The design specified the use of 25.4-mm- (1-in.-) diameter threaded and galvanized steel bars with an ultimate tensile strength of 1,030 MPa (150,000 lb/in<sup>2</sup>), which meets the requirements of ASTM A722 (ASTM 1988). The bars were not uniformly spaced along the face of the deck (Fig. 4). The non-uniform bar spacing creates uneven interlaminar compression along the length of the deck. Interlaminar compression ranged from 1,020 kPa (148 lb/in<sup>2</sup>) at the deck ends to 737 kPa (107 lb/in<sup>2</sup>) at the center of the deck, based on a design force in the bars of 178 kN (40,000 lb). Usually, 690 kPa (100 lb/in<sup>2</sup>) is

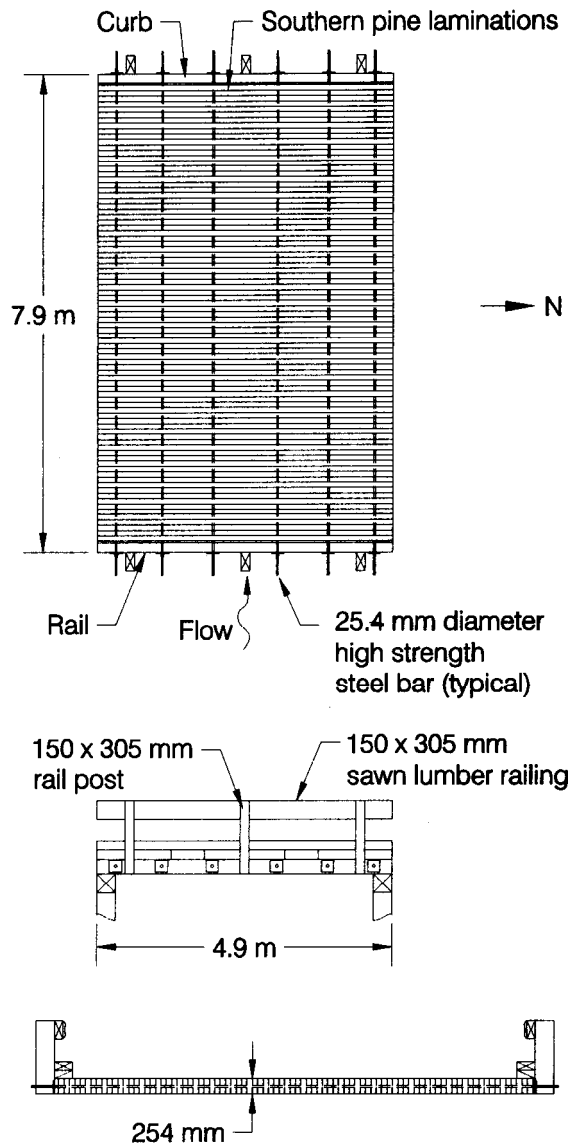


Figure 3—Design configuration of the McCurdy Road bridge.

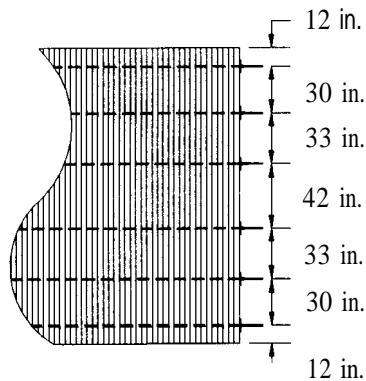


Figure 4—Stressing bar spacing on the McCurdy Road bridge.

the specified interlaminar compression along the entire deck. Steel bearing plates measuring 200 by 200 by 25.4 mm (8 by 8 by 1 in.), steel anchor washers, and spherical hex nuts were specified to anchor the bars along the deck edges.

Design of the bridge rail and curb system was based on AASHTO static-load requirements for vehicular traffic. The bridge rail and curb consisted of a 150- by 305-mm (6- by 12-in.) sawn lumber rail and a 150- by 305-mm (6- by 12-in.) sawn lumber curb with 150- by 305-mm (6- by 12-in.) sawn lumber scupper blocks. The rail and curb were attached to 150- by 305-mm (6- by 12-in.) sawn lumber posts, spaced 1.8 m (6 ft) on center along the bridge edges, starting 0.3 m (1 ft) from the bridge end.

For protection from deterioration, all steel components, including stressing hardware, stressing bars, and anchorage plates, were galvanized in accordance with AASHTO M111 (AASHTO 1990). All wood components were treated with ammonical copper quat (ACQ) preservative in accordance with American Wood Preservers' Association (AWPA) Standard C14 (AWPA 1989). In addition, an asphalt wearing surface and fiberglass reinforced waterproofing membrane were specified for the bridge to protect the deck surface from premature deterioration caused by direct exposure to traffic and the elements.

### Economics

The cost of construction of the McCurdy Road bridge was \$61,809, including labor, materials, plant equipment, and engineering. Ninety-one percent of the total cost was associated with construction, and the remaining 9 percent was the result of engineering and other project support. A detailed cost breakdown is given in Table 1.

Table 1—Project costs.

Description	Cost (\$)	Total (%)
<b>Construction costs</b>		
Labor	13,950	22.57
Equipment	11,628	18.81
Timber materials	27,677	44.78
Misc. bridge materials	2,574	4.16
Other materials	530	0.86
Subtotal	56,359	91.18
<b>Other project costs</b>		
Management	450	0.73
Engineering (design)	5,000	8.09
Subtotal	5,450	8.82
<b>Total</b>	<b>61,809</b>	<b>100.0</b>

A feature of the McCurdy Road project was that the bidding of timber materials included delivery, assembly drawings, and the rental of hydraulic jacks for stress laminating the superstructure. This practice, which is a modification of design building procedures, produced a suitable design at an estimated savings to the project of 25 percent.

The cost of the McCurdy Road bridge can be compared with four projects installed or planned by Richland County. These projects include a simple concrete box culvert similar in crossing size and hydraulic capacity to the original McCurdy Road bridge, a corrugated metal pipe culvert, and two larger concrete culverts designed similar to the roadway width of the McCurdy Road timber bridge.

**Concrete Culvert**– The first project includes the installation of a 1.8- by 4.3-m (6- by 14-ft) concrete box culvert very similar in size and capacity to the original McCurdy Road bridge. The basic culvert materials were bid, including installation by the supplier. The cost of the concrete box culvert was \$71,000 for construction, which included materials and installation.

An additional \$10,000 was expended for engineering, including design, project supervision, and bidding, bringing the total project cost to \$81,000. When compared with the McCurdy Road timber bridge, the cost of this culvert is 33 percent greater.

**Corrugated Metal Pipe Culvert**– The second project includes the installation of a 2.3- by 3.6-m (90- by 140-in.) corrugated metal elliptical culvert pipe 12 m (40 ft) in length. Initial construction of this project was estimated to cost \$38,400, with an additional \$10,000 for engineering and project management. This brings the total cost of the initial installation to \$48,400.

Many rural streams in Richland County are located in an agricultural area with corrosive ground water conditions. Corrugated metal pipes have experienced failure after 15 to 25 years under corrosive water conditions, making total replacement of this project a requirement within the 50-year design life. The total project cost for 50 years is likely to exceed \$100,000, because total replacement would be necessary at least once. If cash flow is an immediate concern, the corrugated metal pipe option may be a viable alternative. However, the total 50-year cost exceeds the cost of the McCurdy Road bridge by 62 percent.

**Larger Concrete Culverts**– The third and fourth projects are concrete culverts designed to replace bridge structures on heavily traveled roads on the county highway system. The third project replaces a small bridge and is intended to accommodate a 7.3-m (24-ft) roadway width, which is equivalent to a 8.5-m (28-ft)

bridge width. The total cost of \$159,400 includes \$129,000 for construction and \$30,400 for engineering. This cost exceeds the McCurdy Road timber bridge cost by \$97,590 or 158 percent,

The fourth project accommodates a 4.2-m (13.8-ft) roadway, widened by 0.6 m (2 ft) on the left for curved and super-elevated pavement. The equivalent bridge width is 7.3 m (24 ft). The total cost of \$138,000 includes \$94,000 for construction and \$45,000 for engineering costs.

A comparison with the two larger concrete culverts was made, because they closely resemble the present width of the McCurdy Road timber bridge.

### Construction

Construction of the McCurdy Road timber bridge was completed by the Richland County Engineer bridge construction staff in June 1995. The construction process included site preparation and installation of the abutments, superstructure, and wearing surface. A detailed account of each step of the process is presented as well as an explanation of the construction schedule.

**Site Preparation**– Site preparation included removal of the existing concrete box culvert structure, excavation of the channel and adjacent bank slope, and removal of the pavement, guardrail, and other incidental items. These activities were required to fit the new bridge in the crossing. Utility relocation was also performed in the initial site preparation phase.

**Abutment Construction**– Abutment construction started by driving twenty-two 30-cm (12-in.) Southern Pine timber piles (Fig. 5). The pile configuration included seven piles per abutment and two in each wing wall. The end pile on each abutment was used to support the inboard end of the wing wall, thereby eliminating the need for one pile on each wall.

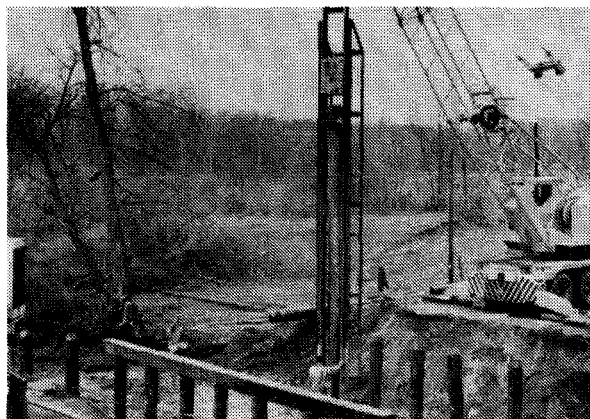


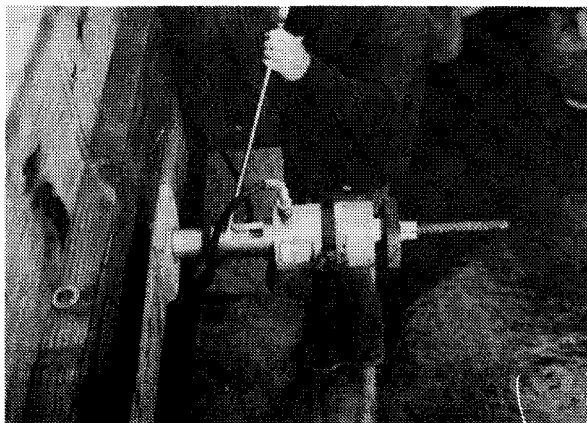
Figure 5–Abutment construction.

Piles were driven to a calculated 22.68-tonne (25-ton) resistance and a minimum drive length of 3.1 m (10 ft). An alternate pile driving plan was available to provide for rock imbedment and concrete encasement of pile tips should it be determined that the 3-m (10-ft) minimum drive become impractical. Driving was done using a 11-kN (2,500-lb) drop hammer; however, a light diesel hammer could easily be substituted in this phase of the work. Each pile cap was constructed using two 30- by 30-mm (12- by 12-in.) timbers that were 4.9 m (16 ft) long. Pile caps were spliced over the center pile using two 75- by 300-by 1,000-mm (3- by 12- by 36-in.) Southern Pine splice plates bolted through the pile caps.

The abutment construction process was completed by installation of the back wall, including the installation of filter fabric on the earth side and the partial backfilling of the abutment to increase construction stability. Installation of the timber caps on the wing walls and final backfilling of the abutment was deferred until completion of the superstructure to provide space for work and allow for final adjustment, if necessary.

**Superstructure**— Construction of the superstructure (deck) was started by placing laminations edgewise on the abutment caps. A total of 210, full-length, 51- by 254-mm (2- by 10-in.) laminations were used in the deck. After the steel bars were inserted through the predrilled holes in the laminations, the bearing plates, washers, and hexagonal nuts were installed on the bar near the deck edges. After all the stressing hardware was installed, bar stressing was initiated.

Bar stressing for the McCurdy Road bridge consisted of four full-design bar tensionings over 5 days. Initially, the bars were slightly tensioned to bring the laminations in uniform contact. Each bar was then stressed to 178 kN (40,000 lb) using a single hydraulic jack (Fig. 6). One day after the first stressing, the bars



**Figure 6—Stress laminating the deck with a single hydraulic jack.**

were again stressed to 178 kN (40,000 lb), following the same procedure as the first stressing. This stressing procedure was completed two additional times: 3 and 5 days after bridge installation. At the completion of the day 5 stressing, elongation of the bars was observed by measuring the bar extension behind the anchor nut.

At the completion of the stressing process, the position of the deck was checked and minor adjustments were made. The deck assembly was then anchored to the pile caps using eight 20- by 610-mm (0.75- by 24-in.) anchor bolts on each end. After the deck was anchored, the timber rail system was attached to the outside edges of the deck.

**Wearing Surface**— Wearing surfaces are specified for each timber bridge deck in Richland County. Previous construction has shown that the detrimental effect of horse shoes, buggy wheels, tire chains, and other items seriously scar the deck surface and significantly accelerate deck degradation.

Richland County specifies a two-phase process using bituminous construction fabrics and 40 mm (1.5 in.) of hot-applied asphalt concrete pavement. Current practice is the use of Chase-Royston 10 AN Easy Pave ER<sup>1</sup> membrane glued to the deck using a solvent material designed for this purpose (Fig. 7). The application of the hot asphalt melts the bituminous material, creating a positive bond between the deck and the wearing surface.

After the wearing surface was applied, the bridge was opened for traffic. The completed bridge is shown in Figure 8.

**Schedule**— The construction schedule proceeded nearly as planned, with a minor delay caused by the spring weather conditions. The only construction-related delay was the delivery of the hydraulic jacks without the proper anchor bolts for the stressing bars. These two delays impeded completion by 7 days. Details of the completed structure are given in Figure 9.

## Future Considerations

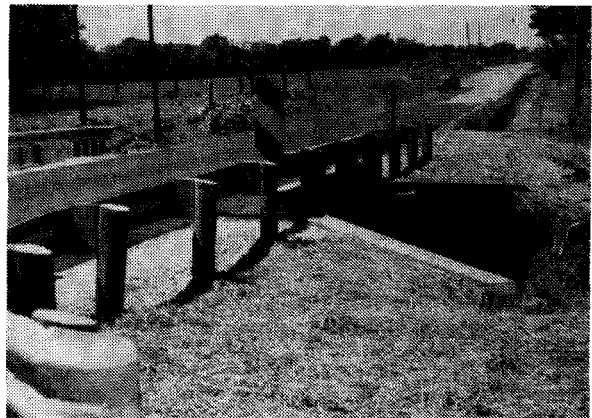
To assess the structural performance of the McCurdy Road bridge, Richland County contacted the USDA Forest Service, Forest Products Laboratory (FPL), for assistance. Through a mutual agreement, a 2-year monitoring program was developed by FPL and implemented through a Cooperative Research and

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<sup>1</sup>The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.



**Figure 7—Application of waterproof membrane.**



**Figure 6—Completed McCurdy Road bridge.**

Development Agreement with the Richland County engineer. Under the monitoring plan, FPL and the Richland County engineer will monitor the moisture content, bar force, static-load behavior, and general structure condition of the McCurdy Road bridge (Ritter and others 1991). The FPL will publish a report of their findings after the completion of the monitoring period.

### **Discussion**

Several lessons were immediately apparent during the construction and initial evaluation phase of the project. Technical information obtained and design opinions developed include considerations in the bearing and anchor plates, stressing bars, lumber treatment, and guardrail specifications.

### **Bearing Plates**

The design of the McCurdy Road structure provided for 200- by 200- by 25.4-mm- (8- by 8 by 1-in.-) bearing plates. Observation of the laminations during the stressing process showed signs of lumber crushing near the bearing plates. The use of larger bearing plates would have decreased or eliminated the amount of crushing.

### **Anchor Washers**

Additional observation of the stressing process showed minor distortion of the washers used as anchor plates. Although not considered critical to the operation of the structure, the substitution of 75- by 75-mm (3- by 3-in.) anchor plates would provide an improvement in workmanship.

### **Bar Spacing**

Bar spacing affects the amount of interlaminar stress introduced in the deck. On the McCurdy Road bridge, the non-uniform spacing combined with the uniform bar force created varying interlaminar stresses in the deck. These variations make it difficult to accurately measure and maintain the required amount of interlaminar stress in the deck. Typically, with decks of this thickness, a 610-mm (24-in.) bar spacing is used with 16-mm (0.625-in.) bars to obtain the required interlaminar stress. Further discussion of this subject will follow in an FPL research report, expected to be published in 1997.

### **Lumber Treatment**

Lumber for this project conformed to industry standards of sawing, finishing, and drying prior to treatment. Because ACQ is a waterborne preservative, the post-treatment moisture content of the treated lumber was very high and was retained in the material at the time of construction. Observations during construction and the post-construction evaluation indicate that the high moisture content may contribute to lumber distortion.

It is suggested that the designer consider a modification of the lumber specifications to provide for post-treatment moisture control. This subject will also be addressed in detail in future FPL reports.

### **Guardrail**

The guardrail assembly incorporated in the project included the use of a steel, deep beam rail face as a primary reinforcement and rub strip per ODOT standards. Evaluation of the completed structure shows that the aesthetic specification of the design objective may have been met by inclusion of the timber rub strip. This consideration does not affect the structure but should be considered to improve the appearance of future structures.

<b>General</b>	<b>Material and Configuration</b>
<p>Name: McCurdy Road bridge  Number: RIC-TR-378-0.40  Structure Number: 7033591  Location: Richland County, Ohio  Date of Construction: June 1995</p> <p><b>Design Configuration</b></p> <p>Number of Spans: 1 (simple beam)  Structure Type: Stress-laminated deck  Total length (out-out): 4.9 m (16 ft)  Skew: None  Clear Span: 4.3 m (14 ft)  Bearing Length: 4.6 m (15 in.)  Width (out-out): 7.9 m (26 ft)  Width (curb-curb): 7.3 m (24 ft)  Number of Traffic Lanes: 2  Design Loading: AASHTO HS-20  Wearing Surface Type: Asphalt Concrete Pavement;  38 mm (1.5 in.) thickness,  ODOT specification 404</p>	<p>Deck:  Species: Southern Pine  Size: 50 mm by 250 mm by 4.9 m  (2 in. by 10 in. by 16 ft)  Grade: No. 2 grade (visually graded)  cut: S4S  Preservative Treatment for all Wood Members:  ammonical copper quat (ACQ)</p> <p>Rails:  Species: Southern Pine  Size: 150 mm by 305 mm by 4.9 m  (6 in. by 12 in. by 16 ft)  Grade: No. 2 grade (visually graded)  cut: S4S  Rub Strip: Deep Beam Rail</p> <p>Posts:  Species: Southern Pine  Size: 150 mm by 300 mm by 1.2 m  (6 in. by 12 in. by 4 ft)  Grade: No. 2 grade (visually graded)  cut: S4S</p> <p>Curb and Scupper:  Species: Southern Pine  Size: 150 mm by 300 mm by 4.9 m  (6 in. by 12 in. by 16 ft)  Grade: No. 2 grade (visually graded)  cut: S4S</p> <p>Stressing Bars:  Type: Dwydag systems  Diameter: 25.4 mm (1 in.)  Number: 6  Design Force: 178 kN (40,000lb)  Spacing: Varies: 305 mm (12 in.),  760 mm (30 in.), 840 mm (33 in.),  1070 mm (42 in.), 840 mm (33 in.),  760 mm (30 in.), 305 mm (12 in.)</p> <p>Anchorage Type and Configuration:  Discrete Bearing Plate, Washer, and Hexagonal Nut  Bearing: 200 by 200 by 25.4 mm  (8 by 8 by 1 in.)  Anchor: 50 mm (2 in.) washer and hex nut</p>

**Figure 9—Information sheet.**

**Concluding Remarks**

Results of this study indicate that it is feasible to build a structurally adequate timber bridge that is economical for the 3.1- to 6.1-m (10- to 20-ft) span length. A comparison of cost shows that a short-span timber bridge structure is a viable option to a conventional concrete and steel bridge or large metal or concrete culverts. Application of a timber bridge design allows

the engineer options that reduce cost and enhance construction capabilities for short-span bridges.

In addition, the McCurdy Road bridge project accomplished Richland County’s two immediate objectives of providing a needed structure to the local commerce system and testing the capabilities of county forces to do the work with locally available equipment.



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Grant Administration: William D. Cuning,  
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