Province of British Columbia

Ministry of Forests

MEMORANDUM

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To: All Regional Bridge/Structures Engineers

From: Vera Pronker
Bridge Engineer
Engineering Section
Timber Harvesting Branch

Re: Existing Glulam Bridges

Enclosed please find the draft of *Procedures for Inspection and Evaluation of Glued-Laminated Bridges*. In its final form, this document should serve as a helpful tool for the engineers involved with the glulam bridges.

Because of the number of peculiarities that distinguish the glulam bridges from other structures, it is sometimes difficult to find consultants with appropriate expertise in this particular field. This report should clarify some of the areas not adequately covered by the Bridge Design Code. Where there was a need to use other sources of information, they were carefully studied and analyzed for their applicability for the logging road glulam bridges in BC. The interpretation of field inspection findings is based, in part, on the report on the same subject, prepared by Dr. Sexsmith, P.Eng., for the Ministry of Forests in December 1992.

Please review this document and comment

Vera Pronker
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Enclosure

PROCEDURES FOR INSPECTION AND EVALUATION OF GLUED-LAMINATED BRIDGES, MINISTRY OF FORESTS

Prepared by: Vera Pronker, P.Eng.
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Date: November, 1993

PROCEDURES FOR INSPECTION AND EVALUATION OF GLUED-LAMINATED BRIDGES, MINISTRY OF FORESTS

Glued Laminated Bridges

The purpose of this report is to provide additional information to engineers who will inspect and evaluate the glued-laminated bridges on forest roads.

This report covers the following topics:

1. Field inspection and interpretation of the condition of the girders
2. Is load-rating of the bridge necessary?
3. Analysis and load-rating
4. References
5. Photo documentation

Evaluation and Load Rating of Existing Bridges
on Resource Roads (Forest and Operations)

1. Field Inspection

Close proximity, thorough inspections shall be carried out to the satisfaction of the engineer responsible for the evaluation of the bridge.

The inspection shall include the following:

(a) Confirmation that as-built plans, when available, accurately represent the bridge. When plans are not available or are not accurate, components shall be measured and all data recorded.

(b) All deficiencies that might possibly affect the load rating and/or the overall integrity of the bridge shall be carefully recorded, possibly noted on the plans, as to the accurate location of the problem areas, so that their effect can be considered in the evaluation.

(c) Inspection findings shall be carefully recorded so that changes in condition observed during future inspections may be assessed (propagation of cracks. etc.)

Most of the bridges on forest roads can be accessed with the ladder as the bridges are relatively short and the height from the creek bed is around 6-8 metres.

Obtain the as-built drawings and previous inspection reports to plan your inspection. From the available documentation, and from discussions with the regional or district staff you will be able to decide which bridges might need inspection access equipment other than a ladder. Probably only every fifth bridge is high enough for a bridge inspection "snooper" truck to be of a real help in accessing the underside of the bridge.

Examine the girders carefully - first just visually, then by tapping (listen for hollow sound - possible pockets of deteriorated wood), inserting narrow and flexible tools into cracks and checking the cracks' depth. A hacksaw blade has proven to be an ideal tool for this purpose. (Drilling and coring can also be used provided the opening will be well sealed with a preservative-treated dowel). Measure the length, location and depth of cracks. If cracks are present, determine what caused them. Most "cracks" are not caused by overstress of the girder, but are actually just surface checks, caused by the swelling and shrinking of wood, and as such do not affect the capacity of the girder section. These cracks developed during the first 2-3 years of the girder's service life and have not changed much since then.

What is a crack?

R.G. Sexsmith, Ph.D., P.Eng., report prepared for the Ministry of Forests, 1992, states:

> " EFFECT OF LONGITUDINAL SPLITS
>
> Inspection of existing glued-laminated bridges often indicates longitudinal cracks of unknown extent. The reduction in shear capacity due to such cracks is difficult to predict. **Where the crack is of limited length (eg a few metres) and limited depth (eg about 1/3 of the thickness or less, then it is unlikely to have a dramatic effect on the capacity, especially if it remains stable through cycles of moisture change and loading.** A crack in which the grain is fully separated is much more severe than a check, in which much of the grain crosses the opening, tying the two sides of an opening with the individual fibres of the grain. The effect of end splits that are through the thickness is analyzed in Appendix A.
>
> The Ontario Bridge Code (1983) gives a shear size effect factor for end splits in existing laminated beams; see clause 13-7.2.2.2.
>
> In order to assess such cracks, inspection methods should include determination of the crack depth and length. This can be done in several ways. Large core drills can be used to remove a core that includes the crack. A special core bit and powerful drill are needed for this. Care must be taken not to make a significant reduction in cross-section when large cores are taken. Several cores would be required along the length of a crack in order to map the extent of the crack. A smaller drill can probe the crack, but the probing must be carried out by someone experienced in interpreting the results, as the drilling does not produce samples that can be interpreted later.

In addition to crack extent, it is useful to try to establish whether or not a crack is stable under load and environmental changes. Cracks can be mapped and tagged, with special tags at the ends, and then revisited at regular intervals. Yearly intervals would be appropriate if the crack is not alarmingly large. A history of the growth of the crack and corresponding load history would assist greatly to determine the cause of the crack. If it grows due to load then it is likely at a critical stress for crack growth and may require a down rating.

There are not accepted procedures for rating when cracks are not at the beam ends. The variability of wood is large, and the stability of a crack is difficult to predict. Where a large crack is found, the beam should be repaired or removed, especially if the crack grows under load cycles.

In order to assess the effect of cracks on safety, a study was performed by Foschi to identify the variation of load capacity with crack length, in terms of the corresponding safety index. As part of the study the effect of past load history was considered.

The most important conclusions from this study are:

1. The safety index increases by about 0.5 for a given case, when the past truck history is accounted for. Another way to express this is to observe that when there are no cracks, the load increases by about 100 kN for the same safety when the past load is accounted for.

2. For the same safety, the load drops rapidly for crack length greater than about 40% of depth. Capacity for cracks at 2 x depth is essentially gone.

Structures with full through cracks with length over half the depth should be considered suspect. However these cracks should not be confused with surface cracks or checks. Coring should be used to probe the depth of existing cracks."

2. Is load-rating of the bridge necessary?

On completion of the inspection and review of all existing documentation, decide if there is a need to evaluate the bridge. The need for an evaluation shall be based on any of the following:

(a) defects, deterioration or damage affecting load-carrying capacity

(b) a review of an existing load posting or previous evaluation

(c) rehabilitation affecting load-carrying capacity

(d) an application for a permit of a new type of truck or vehicle to use the bridge

(e) unsatisfactory performance (deflection, fatigue, serviceability)

Note: All bridge elements and their condition shall be evaluated and appraised according to the usual methods. This paper describes in depth only inspection and evaluation of the glued-laminated girders, but the general integrity and condition of the entire structure needs to be appraised by the engineer.

3. Analysis and load-rating assumptions

Where, based on the condition review or other reasons as stated above, it is necessary to load-rate the bridge, the bridge shall be analyzed for its capacity to carry the following loads:

1. Original design truck (for example - L-100) load, factored and combined with dynamic load allowance, plus dead load.

2. If it is found that the bridge is not capable of carrying the original design load, it shall be analyzed for its capacity to carry the logging truck L-60 or a fraction thereof.

3. The rating vehicle shall be placed on the bridge deck in the usual manner - 60/40 unbalanced axle loads combined with eccentricity 400 mm off the centre of the bridge deck. The heavier loaded wheel line shall be considered to travel along the bridge in such a way as to cause maximum stresses in any of the girders.

   For most situations, the 14.0' wide bridge deck is supported by either 2, 3 or 4 glulam girders. The resultant portions of axle load used for calculating the girder stresses are:

2 girder bridge:	70% of load/girder
3 girder bridge:	55% of axle load/girder
4 girder bridge:	35% of axle load/girder

Transfer all loads and dimensions into metric and analyze the bridge according to limit states method ultimate limit state.

Analyze the girders for flexure and longitudinal shear stresses.

Flexure:

M_{DL} factored + M_{LL} factored ≤ M_r

Shear:

V_{DL} factored + V_{LL} factored ≤ V_r,

where

- resistance in Flexure ..... M_r

  $M_r = \varnothing K_d K_e K_m K_{sb} f_{bu} S$

- resistance in shear .... V_r

  $V_r = \varnothing K_d K_m K_{sv} f_{vu}$ bd/1.5

Strength Properties - glued-laminated girders

- specified bending strength f_{bu} = 28.0 MPa

  (interpolation between wet and dry f values, as the girders are found to have moisture content of less than 19%).

- specified shear strength f_{vu} = 1.87 MPa

  (interpolation wet-dry, based on CSA 086.1)

- resistance factor in flexure for glulam ∅ = 0.9 (based on CAN/CSA-086.1-M89
- resistance factor in longitudinal shear for glulam, ∅ = 0.9
- duration of load factor k_d = 1
- size effect factor for glulam in flexure: k_{sb}
  presently, we use $k_{sb} = V^{-0.086}$ where V = volume of girder in m^3. The new Bridge Code, however, will eliminate this factor for existing girders that were made with "scarf" joints. All available information and testing, that lead to introduction of the size factor, is based only on behaviour of "finger" jointed glulam. Once this factor will be eliminated, it will immediately raise the load-rated capacity in flexure by an average of 13%.

- The size effect factor in shear: k_{sv}
  The National Bridge Code is not very specific when it comes to this factor. It introduced a factor for new structures, but does not mention existing structures. The new OHBDC 1992 covers this subject in the following manner:

  $k_{sv} = 2.3V^{-0.15}$ for new (yet to be built) structures

  where V = volume of girder in m^3.

  $k_{sv} = \frac{75}{\sqrt{d}} \cdot \frac{1}{1+2a/d}$ for existing glulam structures, in which the length of the end split, a, is known. The k_{sv} considered in the shear calculation shall be the lesser of the two above values.

  d = depth of the girder

  a = distance measured from the centreline of the support into the span (length of the end split), in millimetres. Where the split does not extend past the centreline of the support into the span, a shall be taken as 0.

- load-sharing factor, $k_m = 1$

Applied loads and factors

- dynamic load allowance DLA = 0.175

  (based on OHBDC ... 3 or more axles on bridge - DLA = 0.25, reduce by 0.7 for glulam)

  Note: The new edition of the Bridge Code, now under review, will further reduce the DLA by one half. That is, only 0.35 of DLA for span will be the value for structures made of timber or glulam

- dead load factor, α_D (evaluation):

  $\alpha_D = 1.0$

  (based on OHBDC, art. 11-6.3.1: for dead loads use $\alpha_D = 1.0$, provided condition inspection accurately defines them)

- live load factors, αL (evaluation):

  $\alpha_L = 1.25$ (2-girder system)

  $\alpha_L = 1.15$ (3 or more girder system)

  (based on OHBDC, art. 11-6.3(b))

Consideration of the bridge load-carrying history:
When the comparison of the applied load-induced stresses and the resistant stresses would result in down-rating the bridge, a next step needs to be undertaken.

Obtain load-carrying history of the bridge, for at least the last five years. Compare the results of the calculated capacity with the GVW of the traffic that used the bridge. If there were no deficiencies observed during inspection (stress-induced cracks), it is a common practice to raise the posting GVW value by 10-20%, based on the satisfactory past performance of the bridge. A schedule of future inspections needs to be established, in conformance with the *Engineering Manual* (at least every two years), or more frequently, as per the evaluating engineer's recommendation.

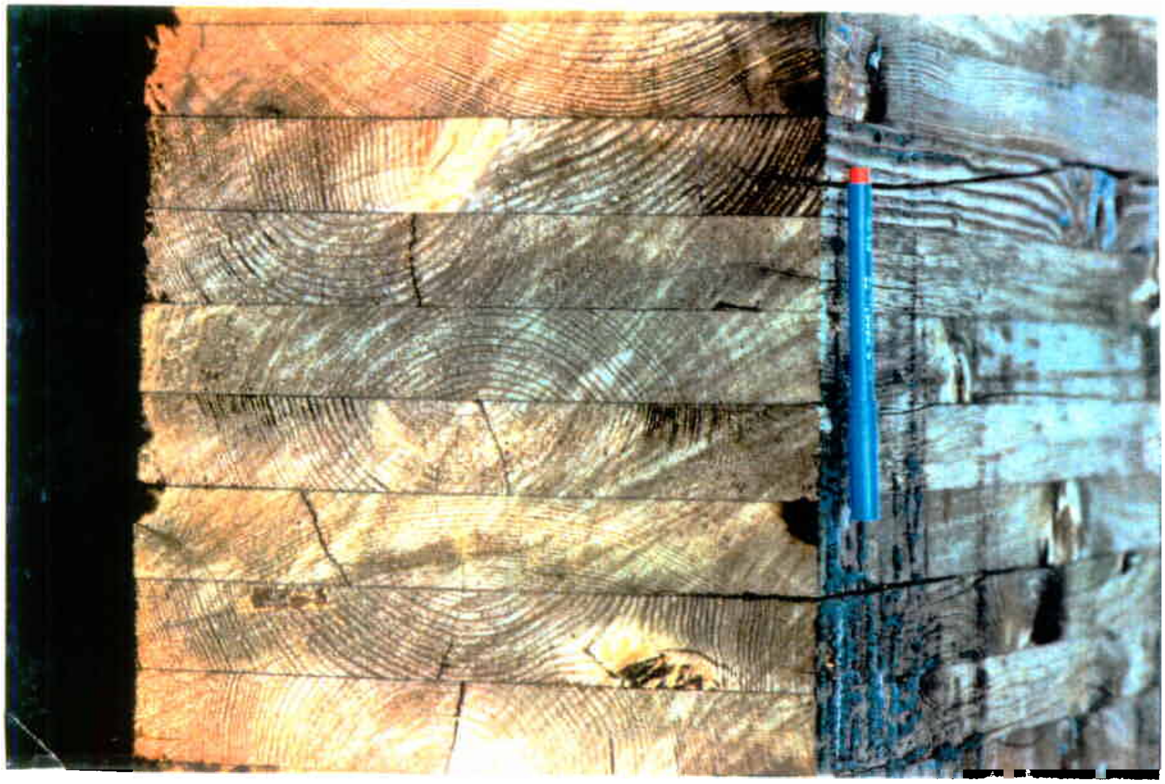
4. References:

- *Engineering Manual*, Ministry of Forests, 1993 Chapter 5, Bridges and Culverts
- CAN-CSA S.6-M88 *Design of Highway Bridges*
- *Ontario Highway Bridge Design Code and Commentary*, 3rd edition, 1992.
- CAN/CSA-086.1-M89 *Wood Design Manual*
- AASHTO: *Standard Specifications for Highway Bridges*, 14th edition, 1989
- *Structural Behaviour of Timber*, Borg Madsen, PhD, PEng, 1992
- *Strength Evaluation of Existing Glued-Laminated Logging Bridges*, Dr. R. Sexsmith, PEng, 1992

5. Photo Documentation

1.

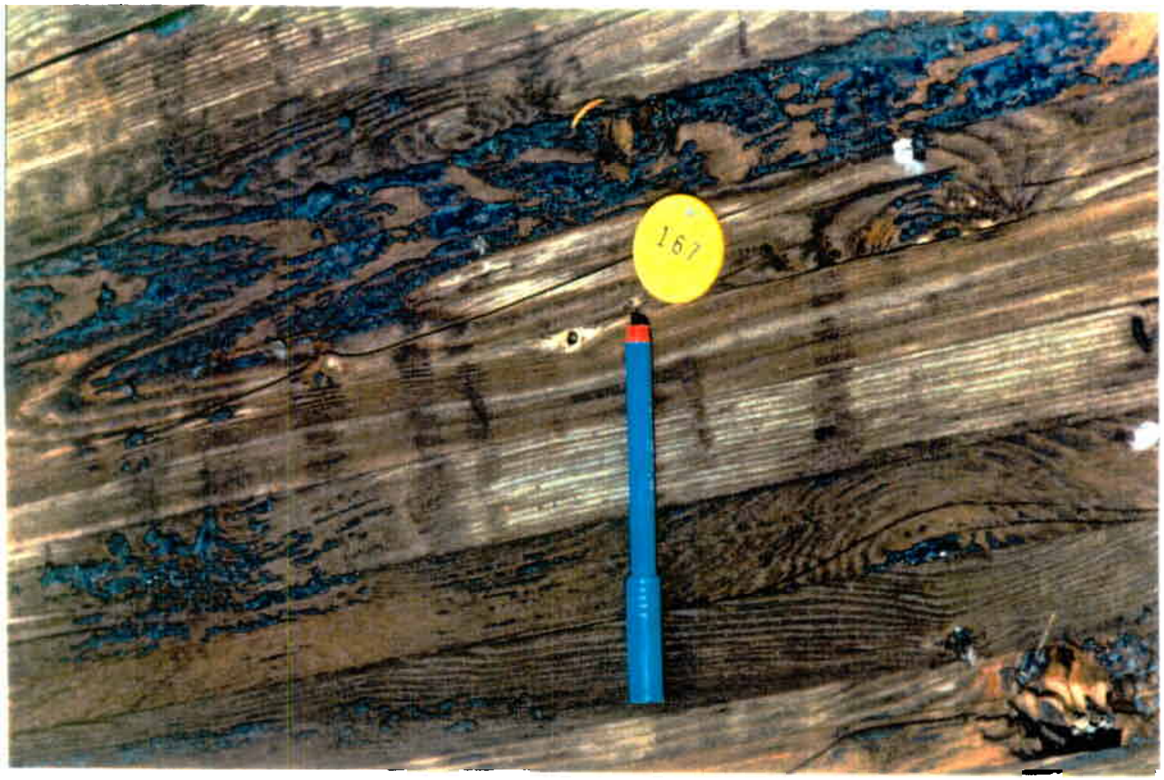
Glued-laminated girders that were taken
out of service, as a result of consultant's
recommendations, due to observed cracks.
These girders are now stored in the service yard
of Cariboo Forest Region.



2.

The bridge girders were cut into 20.0 feet long segments for ease of transportation. It is interesting to observe the extent of the surface checking.These surface checks would certainly not reduce the capacity of the girder section !

(R.Foschi,report on Glulam Girder Bridges, 1992: "Structures with full through cracks with lenght over half the depth should be considered suspect.However, these cracks should not be confused with surface checks or cracks. Coring should be used to probe the depth of existing cracks.")



3.

Cracks were marked by tags by the inspector, in order to observe their possible propagation with time.