# Foamed Plastic Absorbs Staged Post-Tensioning Deflections

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**Abstract:** Staged construction of a long, post-tensioned, concrete highway bridge faces a falsework designer with the alternatives of a costly overdesign of falsework bents for all but a one-time, short-term load or the provision for expensive lowering devices. The problem is solved by using crushable foamed plastic support blocks. The support blocks can be designed to safely support the dead load of the superstructure and to crush when post-tensioning increases the reaction, thus limiting the reaction. While crushing, the blocks continue to provide the necessary support for the superstructure. Stress and strain graphs for foamed isocyanurate are provided, which demonstrate its suitability for this application and provide the basis for design.



## Introduction

The Nehalem River Bridge in Tillamook County, Oregon is a post-tensioned four-stem cast-in-place box girder bridge over the Nehalem River and tidelands of the Pacific Ocean, which is approximately 6 miles downstream. The structure has a total length of 1,062 ft comprising five spans, three of which are 234 ft. The horizontal alignment is in reversing curves.

The superstructure was supported on timber falsework until post tensioning was complete, as shown in Fig. 1. This falsework reached 65 ft above ground line, with as much as 28 ft under water during high tide. Subsurface soil conditions were structurally poor and wood piles to support the falsework were limited to 25 tons per pile. The project was built by F. E. Ward, Inc., of Vancouver, Washington, for the Oregon Department of Transportation.

Construction of the Nehalem River Bridge was done in three stages, as shown in Fig. 2. Post tensioning at each stage created a sequence that is shown in Figs. 3(*a*)–3(*d*). This sequence produced initial upward deflections at joints A and B. When the adjoining stages were stressed, the result was approximately 1-1/8-in. downward movement at each of these stage construction joints. This movement was accompanied by a force that was calculated to be as large as 925 kips, or 231 kips per superstructure stem. This is more than twice the superstructure dead load reaction of 97 kips per stem that the falsework would otherwise be designed for. This paper describes how the falsework designer provided for the downward movement without having to substantially increase the capacity of the falsework.

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## Design Alternatives

The falsework designer was faced with two alternatives: (1) To design the falsework to carry the increased loads due to post tensioning; or (2) to provide a method that would permit downward movement while maintaining continuous support.

Designing the falsework to support the increased load has several drawbacks. It would require more or different materials and increasing the cost. Because of the deep clays and silts at the site, pile group loading considerations would make it difficult to obtain the required support. Add mandatory openings in the falsework for river traffic and this Nehalem River crossing is a perfect example of a situation where loads supported in the subsurface should be kept to a minimum. Finally, even if additional falsework capacity were provided there would remain the problem of gradually releasing the reaction so as to avoid an impact loading on the structure.

If the load must be released gradually it might as well be done during post tensioning. That would avoid the necessity of building extra strong falsework bents. Traditional methods of releaseable support, such as sand jacks or wood wedges, cannot provide the controlled release that is required. Large screw jacks would work, but they are cumbersome and labor-intensive. Hydraulic ram assemblies could do the job, but only with extensive interconnections and relatively expensive power plants and

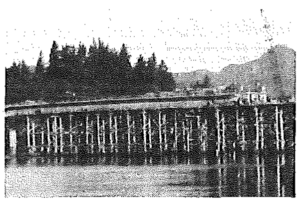

**FIG. 1.—Nehalem River Bridge**

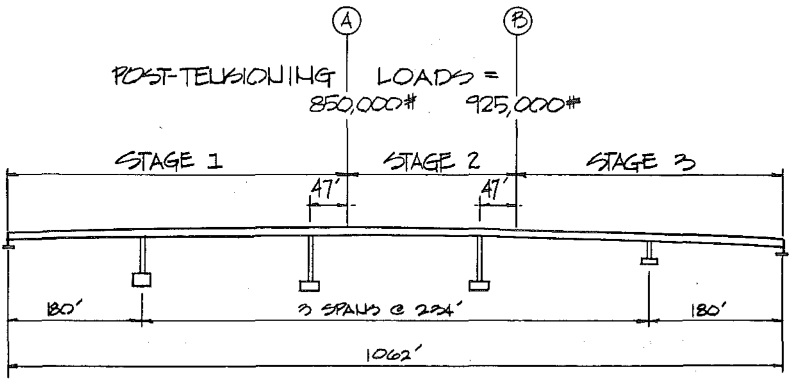


**FIG. 2.—Staged Construction**



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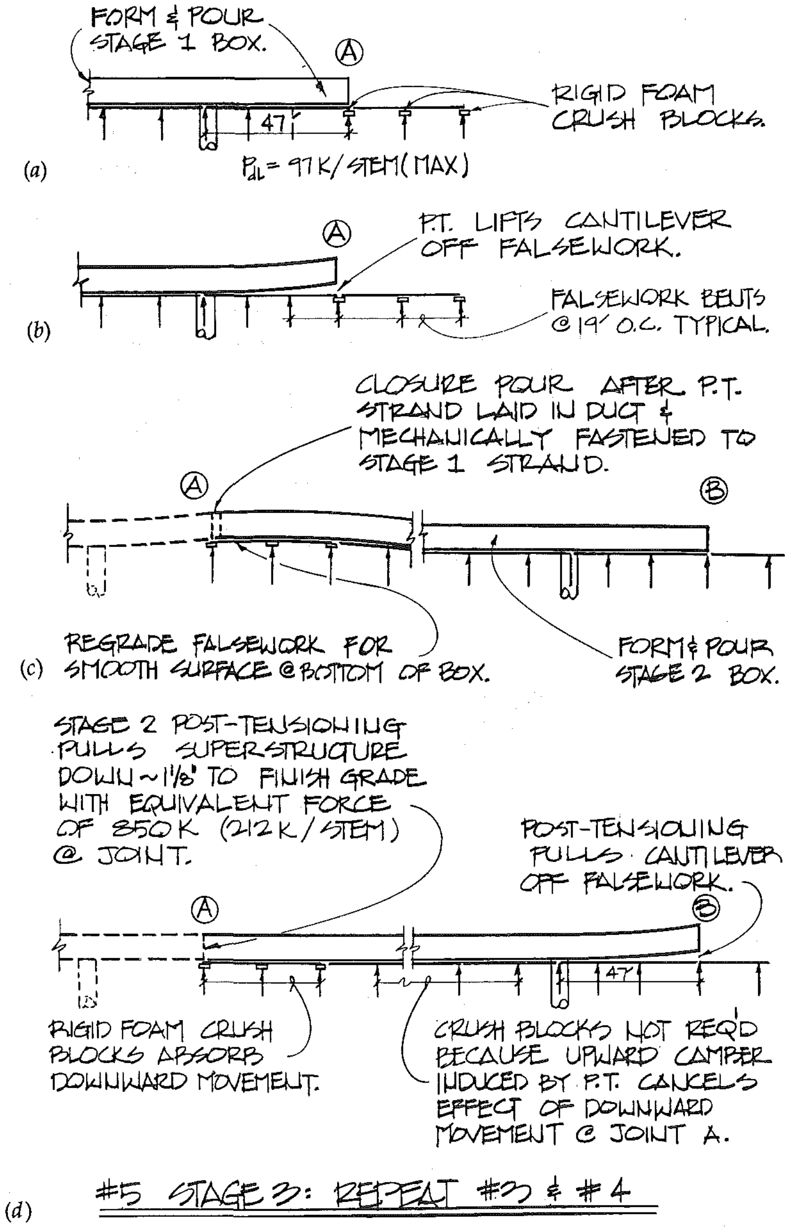


**FIG. 3.—(*a*) Stage 1 before Post Tensioning; (*b*) Stage 1 after Post Tensioning; (*c*) Construct Stage 2 Box; and (*d*) Stage 2 after Post Tensioning**

control panels. These traditional methods all share the same common drawback: The system does not absorb the load, but only transmits the force to underlying support.

## Low-Cost Alternative

A system that offers a clear advantage over these past methods uses rigid foamed plastic crush blocks. They can be engineered to absorb these large post-tensioning deflections while continuing to provide the necessary support for the structure itself. One plastic that lends itself to this application has the generic name of *isocyanurate*. The structural strength of isocyanurate depends on how dense it is at time of manufacture; yield stresses range from 300 psi at 3 pcf density to over 1,500 psi at 25 pcf. Isocyanurate is manufactured by mixing two common liquid plastics, isocyanate and polyol, in the presence of a catalyst. An exothermic reaction takes place that generates temperatures in the range of 250–300° Fahrenheit. This heat combines with previously added liquid freon or water to cause the plastic to expand or foam. The heat also contributes to the curing process, which takes about 30 days. Although initially cast in 18-in. × 20-in. × 100-in. buns, the rigid foamed plastic is easily cut into any size by a power saw.

The plastic blocks must be designed so that they will support the dead load of the superstructure, up until the time of post tensioning. This must be done without excessive deflection either from the initial loading or from creep. Fig. 4 shows that for this plastic foam, initial strain is approximately 5% and creep is very small when the blocks are loaded to 60% of their yield strength. For higher loading, both initial strain and creep become unacceptable. By judicious choice of density and size, the unit stresses in the plastic block due to dead load are kept at about 60% of yield.

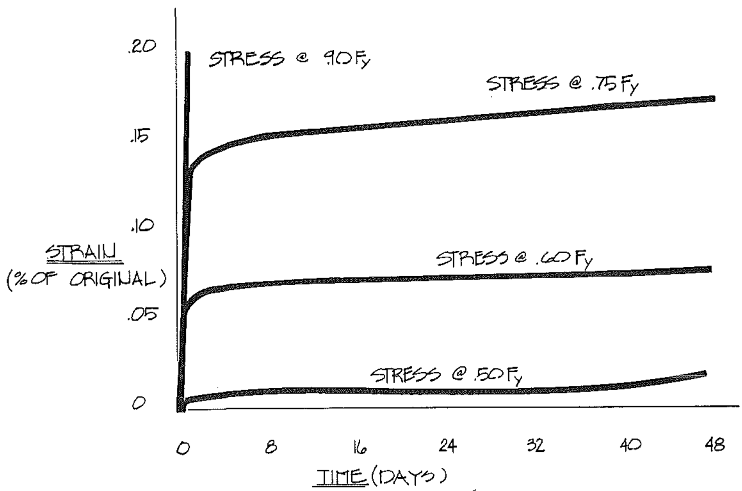


**FIG. 4.—Time-Department Strain Characteristics of Isocyanurate**



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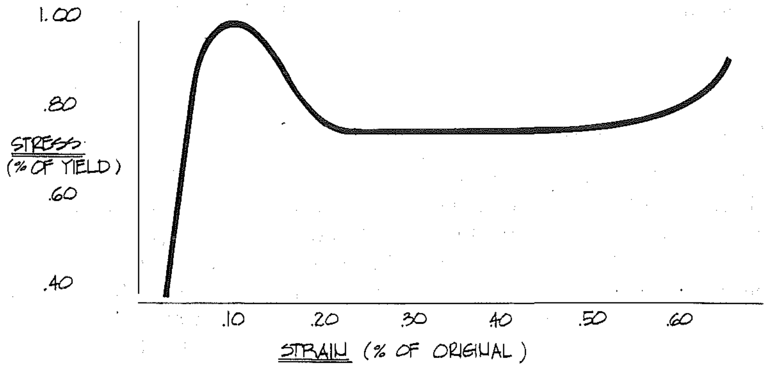


**FIG. 5.—Isocyanurate: Stress versus Strain**

Fig. 5 is a stress versus strain graph for isocyanurate. During post tensioning, the load increases on the block until it reaches yield. It is at this point that the falsework is most highly loaded. The blocks yield, providing a controlled crush, but always maintaining support at least equal to the weight of the superstructure. The plastic foam has a liberal zone of crush before strain hardening sets in. Once strain hardening begins, loads will be transmitted into the falsework rather than absorbed in the blocks. By limiting crush to between 40 and 45% of the original thickness, and knowing the possible deflection due to post tensioning, plus an appropriate safety margin, the engineer can calculate the necessary thickness of the virgin foamed plastic crush block. In Nehalem, we provided for a maximum deflection of 1-5/8 in. by building the blocks 4 in. high.

In addition to being structurally effective, the foamed plastic crush blocks are practical as well. They are compact and lightweight, making

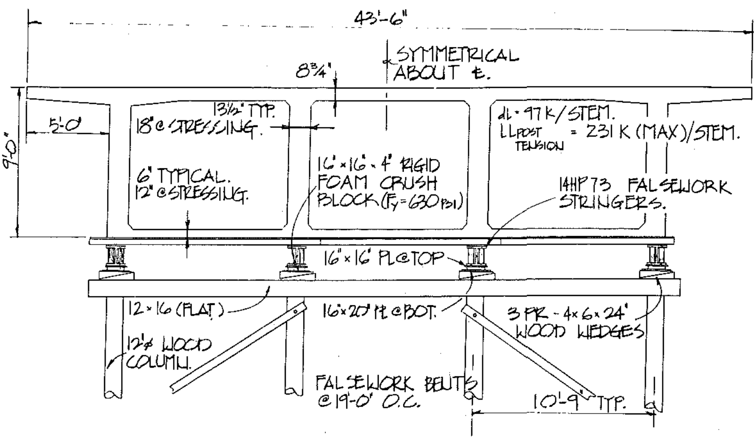


**FIG. 6.—Section View: Nehalem River Bridge**

for easy handling by workers. Because the blocks tend to be brittle, removing them after post tensioning was simple. A hand or power saw, chisel, or claw hammer crumbled the blocks in short order. The properties of isocyanurate are not adversely affected by the construction environment or weather. Rigid foamed plastic is not expensive, and its use proved to be very cost-effective.

Fig. 6 is a cross section that shows the arrangment of falsework using the rigid foamed plastic crush blocks. The wood wedges are there to provide for accurate grading in the initial setting of the bottom soffit. The steel plates were necessary to provide larger bearing areas so that unit stresses in the wood and the foam blocks were at acceptable levels.

## Cooperation of Contractor, Owner, and Supplier

As far as we know, this is the first time a rigid foamed plastic has been used to control deflections caused by post tensioning. Credit for its success is shared equally by three organizations. The contractor provided an environment where a manageable workload for his engineering staff allowed time to thoroughly analyze the problem and research a practical solution. Further, there is an emphasis on efficient and effective solutions to a problem rather than traditional methods of accomplishing a task. The owner was open-minded in a professional manner about untried construction methods. He also maintained open channels of informal communication between the contractor and owner at the project-management and staff-engineering levels. Finally, the owner resisted the temptation to overplay the need for legal participation in what was essentially an engineering activity. The material supplier, General Plastics Manufacturing Company of Tacoma, Washington, talked plastics engineering in common-sense terms and reduced technical jargon to plain speaking. They were flexible in thinking about new applications for their products, and they were willing to make the initial investment of time and research support to complement the contractor's engineering efforts.

## Conclusion

Blocks of foamed isocyanurate have successfully been used to limit falsework reactions while providing continuing support during stage post tensioning of a long prestressed concrete highway bridge. The blocks are inexpensive, easy to use, and performed in the manner anticipated by the designer.

## Appendix.—Metric Equivalents

| | | |
|---|---|---|
| 1 in. | = | 2.54 cm |
| 1 ft | = | 0.304 m |
| 1 mile | = | 1.61 km |
| 1 kip | = | 4.448 kN |
| 1 ton | = | 8.8964 kN |
| 1 psi | = | 6.89 kPa |



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