Literature Search:
Modular Bridge Construction

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Summary of Results

The purpose of this literature search is to identify reports, studies, or examples within the last decade of minimally disruptive forms of quick-build or modular overpass construction projects over a two-lane highway, preferably using pre-cast, open-bottom box culverts. The specificity of this search reduces available results to one study of precast concrete segmental box culverts. It is included as the first annotation.

Expanding the search beyond box culverts to other forms of modular or quick-build bridge overpass or flyover construction revealed eight additional studies and reports under the general topic of *accelerated bridge construction* (ABC) or *prefabricated bridges*. These sources discuss the following materials:

- Tied-arch with free-standing arches
- Precast full-depth deck panels on prestressed inverted tee girders
- Glulam timber bridges
- Modular flyover bridge (aka ASTRA)
- Modular join for accelerated fabrication and erection of steel bridges
- Short-span innovative bridge elements and systems suitable for local government
- Self-propelled modular transporter
- Expanded polystyrene (EPS) geofoam

Publications that were found but not incorporated into this literature search because they fell outside the parameters of the search request include guidelines, studies on overpass effectiveness, as well as research and projects on improving intersections with flyovers or overpasses that were not quick builds.

Annotated Bibliography

The following nine annotations are the most applicable studies and reports published within the previous ten years that relate to temporary quick-build or modular highway overpasses or flyovers. Links and abstracts are listed with the citations; links open to full-text documents, pages that allow PDF downloads, or abstract pages. Articles and papers not openly available in full-text can be obtained through interlibrary loans. Please reach out to the Oregon DOT librarian for access.

Precast Concrete Box Culvert

The following citation is the only report found within the previous ten years that relates to box culverts with a reference of use as an overpass.

Jain, P., & Suryawanshi, S. R. (2022). A Research paper on analysis and design of precast box culvert with vehicular loading. International Research Journal of Engineering and Technology (IRJET), 09(05), 568 – 573. https://www.irjet.net/archives/V9/i5/IRJET-V9I5185.pdf

> Buried structures serve a variety of purposes. They are typically used for conveying water. At other times they're accustomed provide a grade separated crossing for pedestrian and vehicular traffic . Various structures and material types are used. The most common types are box and pipes culverts. Precast concrete segmental box culverts are one among the foremost versatile and cost-effective pre-cast concrete products, meeting the requirements of fast paced construction projects. Flexibility in design and simple placement at site results in cost savings. There are many uses for pre-cast concrete segmental box sections as they can ease the construction work. These monolithic structures can be used for underpasses, service tunnels, subways, small bridges, storm water culverts, cattle underpass etc. These guidelines are only applicable for Precast Concrete Segmental Box Culverts. A Precast Concrete Box Culvert is an easy construction with segmental construction which is used to provide passage for roads, flowing water below roads, embankment or railways. Precast concrete segmental box culverts are popular in construction where time available for construction is less. With today's technology these precast box culvert can be constructed unto 40 - 60 m length of per day with precast sections available at site. To achieve this productivity at site these segments of finished section of required shape must be available in precast yard. Big size box culverts having transportation issue shall be transported as one unit are constructed from one ‘U’ sections and top slab casted separately; for on-site assembly. Sometimes two ‘U’ shapes s also are getting used . These are given rebated joints/V notched to permit sections to be laid open or sealed. Precast head walls and wing walls can also be provided for Precast Concrete Box culverts.

Quick-Build or Modular Bridge Construction

The following eight reports and studies relate to quick-build or modular bridge construction other than box culverts.

Amunugama, H., Attanayake, U., LaViolette, M., Wagner, B. M., Longfield, M., Pakala, P., & Belcher, J. A. (2025). Monitoring during the unbraced network tied-arch bridge construction using ABC techniques. Transportation Research Record, 2680(2), 1172 – 1198. https://doi.org/10.1177/03611981251368841

> A unique network tied-arch bridge with free-standing arches was designed to carry the 2nd Avenue traffic over the Interstate (I) 94 in Detroit, Michigan. This 245-ft-long, 96.5-ft-wide, and 18° skew bridge is the first skewed unbraced network arch bridge in the United States. The skeleton of the superstructure was erected off-site at a bridge staging area and moved and placed over the I-94 freeway using self-propelled modular transporters to complete construction. Based on the observations from the analysis models and the communications with the Michigan Department of Transportation, the Engineer of Records, and the peer review engineer, an instrumentation system was designed and installed in the bridge to: (i) monitor and record strains in major components during construction to determine the state of stress after construction; (ii) monitor and record the change in strains during service life to support bridge maintenance and load rating decisions; and (iii) collect adequate data to verify design assumptions. This paper discusses instrumentation system planning, design, and implementation, including sensor locations, data acquisition systems, cable and power management, data collection, and observations. The instrumentation system functions as expected. The monitoring data confirm that the structural component strains are within the design limits and the structure functions as expected.

Bartlett, S., & Neupane, R. (2017). Seismic evaluation of Expanded Polystyrene (EPS) geofoam bridge support system for overpass structures (MPC 17-328). North Dakota State University - Upper Great Plains Transportation Institute, Fargo: Mountain-Plains Consortium. https://www.ugpti.org/resources/reports/details.php?id=900

> Expanded Polystyrene (EPS) geofoam is a super-lightweight material used in various transportation engineering applications. It has been particularly successful as an ultra-lightweight alternative to earthen, geosynthetic reinforced soil (GRS), and mechanically-stabilized earth (MSE) embankment systems when deployed as an approach embankment for highway bridges located atop soft soil sites. The goal of this study is to extend the application of EPS geofoam to that of directly supporting relatively lightweight bridge structures without the need of installing intermediate or deep

foundation systems or using ground improvement to stabilize the foundation soils. This study evaluates the concept of using EPS blocks to support two-lane, single-span highways and pedestrian bridge structures under gravity and seismic loads. If the concept is successfully established, an EPS bridge support system might significantly contribute to accelerated bridge construction (ABC) technologies for certain classes and sizes of bridge structures. The deployment of this technology may lead to rapid and more economical deployment of bridge foundations for permanent and temporary bridge structures in areas plagued with soft ground issues that hamper or limit the use of conventional embankment and bridge support construction (e.g., large consolidation and post-construction creep settlement, low bearing capacity, poor construction conditions, relocation of buried utilities, and potential settlement damage to adjacent structures and foundations).

Carnahan, Z., Mingo, M. Tazarv, M. & Wehbe, N. (2019). Development of alternative bridge superstructures for South Dakota local roads (MPC-19-373). North Dakota State University - Upper Great Plains Transportation Institute, Fargo: Mountain-Plains Consortium. https://www.ugpti.org/resources/reports/details.php?id=934#quick_citation

The South Dakota Department of Transportation (SDDOT) allows the use of precast double-tee bridges in counties because they are economical and fast in construction. Alternative durable prefabricated bridge systems are needed to provide more options to local governments. The present study was carried out to investigate the feasibility of alternative prefabricated bridge systems that can be incorporated in South Dakota. The project technical panel approved testing of two superstructure bridge systems: (1) precast full-depth deck panels on prestressed inverted tee girders and (2) glulam timber bridges. The present report includes the design, construction, testing methods, and recommendations for the selected bridge alternatives. Three full-scale bridges, one fully precast and two glulam timber, were tested under fatigue and ultimate loading. The precast bridge specimen was 50-ft long by 9.5-ft wide. No significant damage beyond the prior-to-testing shrinkage cracks was observed throughout the entire fatigue test, and the overall bridge stiffness did not deteriorate. The strength load testing showed that the load amplitude at the first crack was higher than the AASHTO Service and Strength I limit state loads, indicating sufficient performance. Based on the construction, testing, and cost analysis, it was concluded that the precast full-depth deck panels on prestressed inverted tee girder bridge is a viable alternative to the double-tee girder bridge. The full-scale glulam girder bridge test model was 50-ft long and 9.25-ft wide. The full-scale glulam slab bridge was 16.5-ft long and 8-ft wide. Both timber bridge types showed minimal damage during fatigue testing. The only damage to the girder timber bridge was cracking of tongue-and-groove deck-to-deck connections, which can

be eliminated using flat-end panels. Ultimate testing of the two bridge systems confirmed that the AASHTO design method for timber bridges is adequate. Girders of glulam bridges should be designed as fully non-composite members. Based on the construction, testing, and cost analysis, it was concluded that both types of glulam timber bridges are viable alternatives to the double-tee girder bridges.

Coxworth, B. (2024). Portable bridge unlocks road construction without traffic diversions. New Atlas. https://newatlas.com/good-thinking/astra-bridge-modular-mobile-flyover/

A new modular mobile flyover bridge allows vehicles to drive right overtop of stretches of highway roadwork, instead of waiting to go around them. Known as the ASTRA Bridge, it's intended to make life easier for motorists and safer for roadway workers.

Jones, A., & Oppong, K. (2021). Bridge structure alternatives for local roads (MPC-21-433). North Dakota State University - Upper Great Plains Transportation Institute, Fargo: Mountain-Plains Consortium. https://www.ugpti.org/resources/reports/details.php?id=1036

Local governments have an immediate need for low life-cycle cost bridge replacement alternatives. Knowledge of available alternatives and construction planning processes hold potential for South Dakota local governments to replace more structurally deficient local bridges with limited funds. Through extensive literature review of research articles, reports, and existing practices within and outside South Dakota, a comprehensive list of short-span innovative bridge elements and systems that are suitable to implement at the local government level has been established. The list was converted into a catalog and divided into techniques, superstructures, substructures, materials, and entire bridge structures. The techniques include using prefabricated bridge elements and systems and the jointless bridge. Emphasis was maximum economy with mass-production of prefabricated components. An estimate of cost was developed for the alternatives listed in the catalog. The cost for each alternative provides a somewhat reliable representation of the average cost of the item per square foot of deck, and was obtained from the literature and state Department of Transportation websites. A list of administrative requirements on local bridge replacements without South Dakota Department of Transportation or federal assistance was ALSO compiled and included in this report. An evaluation procedure with simple inputs for use by local government decision making was developed. It is the intent that this checklist will lead decision makers through the process of cost and performance evaluation, and finally recommend if the project should be completed locally or using a federal program.

Tazarv, M., Carnahan, Z., & Wehbe, N. (2019). Glulam timber bridges for local roads. Engineering Structures, 188. 11 – 23. https://doi.org/10.1016/j.engstruct.2019.03.012

Glued-laminated (glulam) and cross-laminated timbers are gaining interests in bridge engineering community due to their improved strength and enhanced durability compared to sawn lumber. The main bridge type on South Dakota local roads is a precast prestressed double-tee girder bridge, which has only one supplier in the state. In an attempt to provide more bridge type selection options for local governments, the system performance of two types of glulam timber bridges was investigated through full-scale experiments. One glulam girder bridge and one glulam slab bridge were tested under fatigue and strength loading. Both bridge types showed minimal damage during the fatigue testing and the bridge stiffness remained constant. Strength testing of the two bridge systems confirmed that the AASHTO method of design for timber bridges is adequate. Girders of glulam girder bridges should be designed as fully non-composite members. A cost analysis showed that the superstructure cost of glulam timber bridges can be 30–50% lower than the precast prestressed double-tee bridge superstructure cost. Based on the construction, testing, and cost analysis, it is concluded that both types of glulam timber bridges are viable alternatives to precast prestressed double-tee bridges to be used on local roads.

Tumbeva, M. D., Trhall, A. P., & Zoli, T. P. (2021). Modular joint for the accelerated fabrication and erection of steel bridges. Journal of Bridge Engineering, 26(6). 04021022. https://doi.org/10.1061/(ASCE)BE.1943-5592.0001706

This paper introduces a new strategy for the accelerated fabrication and erection of steel bridges: a modular joint. The modular joint is a prefabricated, nodal connector composed of a weldment/built-up section of webs and flanges that includes a starter segment for each connecting member. It joins standard rolled wide flange sections through bolted splice connections in double shear. Flanges and webs are connected independently, forming a moment-resisting connection. This provides flexural stiffness for truss-like or beam-like behavior and provides the potential for the structure to tolerate member loss. The flange splice plates connecting the joint and any member can be bent to varying angles to achieve a variable depth geometry. This is a “kit-of-parts” approach, where members are standard sections and the prefabricated modular joint can be repeated throughout a single structure and also used for many structures. Although this approach retains all the advantages of modular construction (e.g., prefabrication, mass production, rapid erection, and reusability), it overcomes the prime deficiency of the existing technologies that a fixed panel size limits the span length. This paper investigates this approach through (1) developing a methodology to achieve rational

constant- and variable-depth bridge forms, (2) performing structural optimization for minimum self-weight while meeting structural performance demands and transportability criteria, and (3) demonstrating the promise of this approach through detailed finite element numerical analyses.

Yu X, Wang H, Jing H. (2022). Support position optimization with safety factor in the demolition and rebuilding of a bridge using the SPMT method: A case study. Advances in Structural Engineering. 2022;25(8):1701-1713. doi:10.1177/13694332211053692

The accelerated bridge construction (ABC) method has become increasingly popular in recent decades because it creates few traffic disruptions, minimal environmental impacts, and lower cycle costs. The self-propelled modular transporter (SPMT) is an ABC method. In the SPMT method, the support position is a key factor during transportation because the support position changes the boundary conditions and consequently changes the stress distribution of the original bridge. Unreasonable stress distribution may cause a collapse of the demolished bridge and permanent damage to the new built bridge during the transportation process. In the present study, an overpass bridge is demolished and replaced due to the expansion of an expressway. The SPMT method is adopted for rapid demolition and construction because it can greatly reduce traffic interruptions and costs. An optimization strategy of SPMT support positions is proposed by introducing a safety factor. The influence of the support positions of the SPMT on the internal force, stress, deflection, and resistance to overturning of both the demolished and new built bridges during the transport process is considered in the safety factor. Finally, an overpass bridge is taken as a case study. The optimal support positions of both demolished and new built bridges are obtained, and the demolition and rebuilding of the bridge are successfully completed using the SPMT method.

Questions?

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