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U. S. Department of Commerce
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Applied Economics Office
Engineering Laboratory
Gaithersburg, MD 20899

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Sponsored by:

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U.S. DEPARTMENT OF COMMERCE
Gary Locke, Secretary

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Patrick D. Gallagher, Director

Abstract

This report presents a proposed UNIFORMAT II classification of bridge elements. Elemental classifications differ from traditional product-related classifications because their core concept is an element that performs a given function, regardless of the design specification, construction method, or materials used. The proposed classification represents a major revision and restructuring of ASTM Standard Classification E 2103, a bridge-related standard classification first issued by ASTM in 2000. The original bridge classification, E 2103, differed from the UNIFORMAT II elemental classification hierarchy in several ways which limited its applicability. The major revisions to E 2103 described in this report will promote its relevance, understanding, and acceptance in the bridge industry. Once approved and reissued by ASTM, the UNIFORMAT II Standard Classification of Bridge Elements, E 2103, will provide the basis for a comprehensive data set of bridge-related costs that will enable public and private decision makers to choose more cost-effective solutions for the design and construction of new bridges and the maintenance and repair of existing bridges across the Nation.

A set of alphanumeric designators for the proposed multi-level bridge classification is included. Because many users are interested in constructing databases for use in cost analyses associated with project planning, design, construction, maintenance and repair, and condition assessment, alphanumeric designators provide the basis for compiling, organizing, and referencing cost data.

This report also includes a proposed list of sub-elements for bridges. The UNIFORMAT II hierarchy consists of three levels: Level 1, Major Group Elements; Level 2, Group Elements; and Level 3, Individual Elements. Thus, the core concept of an element resides at Level 3. However, because elements are major components of a constructed entity, there is often ambiguity of what exactly is included in an Individual Element and what should be rightfully excluded from it. Because sub-elements can be tied into a work breakdown structure, they significantly enhance the usefulness of an elemental classification across all project participants throughout the lifecycle of bridges and other constructed entities.

Keywords:

Bridges; construction; cost estimation; economic analysis; functional elements; life-cycle cost; risk analysis; standards; UNIFORMAT II; value engineering

Preface

This report produces a proposed classification of bridge elements that will provide the basis for a standard classification of bridge elements to be issued by ASTM International. The material presented in this report will also provide the basis for a comprehensive data set of bridge-related costs that will enable public and private decision makers to choose more cost-effective solutions for the design and construction of new bridges and the maintenance and repair of existing bridges across the Nation. The intended audience is the National Institute of Standards and Technology, the bridge industry, standards and codes developers, the American Association of State Highway and Transportation Officials, the American Society of Civil Engineers, and other construction industry stakeholders interested in improving interdisciplinary communications and in reducing the costs of designing, constructing, and maintaining the Nation's physical infrastructure.

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Disclaimer Regarding Non-Metrics Units

The policy of the National Institute of Standards and Technology is to use metric units in all of its published materials. Because this report is intended for the U.S. construction industry that uses U.S. customary units, it is more practical and less confusing to include U.S. customary units as well as metric units. Measurement values in this report are therefore stated in metric units first, followed by the corresponding values in U.S. customary units within parentheses.

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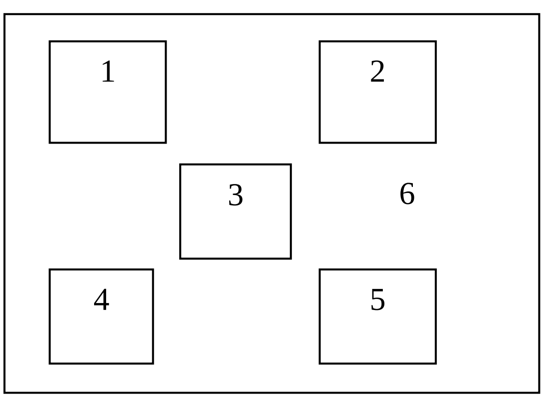

The bridges associated with each cover photograph are as follows: (1) Chicago Skyway, Chicago, Illinois; (2) Gateway Arch Bridge, Taylor, Michigan; (3) Abe Lincoln Memorial Bridge, LaSalle County, Illinois; (4) I-39 over Kishwaukee River, Winnebago County, Illinois;(5) USH 12 over Coffee Creek, Black River Falls, Wisconsin; and (6) ghosting of the Gateway Arch Bridge superstructure.

Author Affiliations

Muthiah Kasi, PE SE CVS, serves as Chairman of the Board at Alfred Benesch & Company. Mr. Kasi joined Alfred Benesch & Company in 1969. His experience at Benesch includes design and management of high rise and low rise buildings, long span river bridges and short span bridges, and urban and rural highways. Mr. Kasi is the Chairman of the ASTM Subcommittee on Building Economics, where for nearly 20 years he has been active in developing standards covering the design, construction, and operation of constructed facilities.

Robert E. Chapman, Ph.D., is the Chief of the Applied Economics Office in the Engineering Laboratory at the National Institute of Standards and Technology (NIST). Dr. Chapman joined NIST, formerly the National Bureau of Standards, in 1975. As Chief of the Applied Economics Office, he leads a group of economists that evaluate new technologies, processes, government programs, legislation, and codes and standards to determine efficient alternatives and measure their economic impacts. Since 1998, Dr. Chapman has chaired the Task Group on Techniques within the ASTM Subcommittee on Building Economics.

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1 Introduction

1.1 Background

The use of elemental classifications for improved budget planning and cost control for building-related projects began shortly after the end of World War II. Elemental classifications differ from the traditional “product-related” classifications because their core concept is an “element” that performs a given function, regardless of the design specification, construction method, or materials used. Thus, elemental classifications support a structured approach for developing budget estimates during the planning and conceptual design stages where quantity takeoffs and other product-related information are still under development.

The initial applications of elemental classifications were in the UK, where they were used for budgeting funds to repair educational facilities damaged or destroyed during World War II and to build new facilities to meet increased demands due to population growth. The UK successes with budgeting and cost control for educational facilities led to applications in other building types within the UK and ultimately in other parts of Europe. By the 1960s, the use of elemental classifications for budgeting and estimating the costs of the design and construction of commercial and institutional buildings had spread throughout the British Commonwealth and many other parts of the world.[1]

The use of elemental classifications for commercial and institutional buildings in the USA began in the 1950s. These initial applications were led by the General Services Administration (GSA) and the American Institute of Architects (AIA). The interest in producing a common framework that could be used by all stakeholders in the design, construction, and operation of commercial and institutional buildings led to the creation of UNIFORMAT in 1975.[2]

The initial success of UNIFORMAT stimulated interest in expanding its capabilities to other types of constructed entities. In the late 1980s, a broad-based effort under the auspices of the Building Economics Subcommittee of ASTM International was launched to produce a standard classification of building elements and related sitework.[3] The resulting standard, E 1557, was first issued by ASTM in 1993. Over the ensuing years, E 1557—refered to as UNIFORMAT II to highlight its linkage to the earlier UNIFORMAT document—has been revised and expanded to meet new and emerging needs.[4]

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[1] Royal Institute of Chartered Surveyors (RICS). 1969. *Standard Form of Cost Analysis*. London, England: The Building Cost Information Service.

[2] Hanscomb Associates, Inc. 1975. *Automated Cost Control and Estimating System*. Washington, DC: General Services Administration.

[3] Brian Bowen, Robert P. Charette, and Harold E. Marshall. 1992. *UNIFORMAT II: A Recommended Classification for Building Elements and Related Sitework*, NIST Special Publication 841. Gaithersburg, MD: National Institute of Standards and Technology.

[4] ASTM International. “Classification of Building Elements and Related Sitework—UNIFORMAT II,” E 1557, *Annual Book of ASTM Standards: 2010*, Vol. 4.11. West Conshohocken, PA: ASTM International.

The latest version of E 1557 focuses primarily on buildings but has broad applicability to other types of constructed entities. Current applications of E 1557 include: planning estimates; program estimates; preliminary project descriptions; preliminary construction schedules and cash flow projections; design phase estimates; CAD layering and building information modeling (BIM); life-cycle cost analysis reporting; checklists for technical design reviews; project scheduling; construction progress reporting and interim payments; construction claims analysis; building condition assessment; organizing design, engineering, and construction cost information for manuals and databases; and organizing maintenance and life-cycle cost data.[5]

The widespread use of E 1557—it is one of the top selling standards from ASTM's inventory of over 12 000 standards—sparked interest in standard classifications for other types of constructed entities. Several ASTM standard classifications were subsequently developed, most notably a bridge-related classification, E 2103.[6] However, standard classification E 2103 differed from the underlying "elemental" concept that was at the heart of E 1557. To address the need for a more rigorous "family" of classification standards based on the UNIFORMAT II elemental concept, the Building Economics Subcommittee, ASTM E06.81, formed a task group charged with the development of a set of "Guidelines for Developing UNIFORMAT II Standard Classifications."[7] The UNIFORMAT II Guidelines were first approved by the Building Economics Subcommittee in April 2009 and were posted on the ASTM E06.81 web site in May 2009.[8]

Because bridges are a critical component of the Nation's infrastructure and many bridges are in need of significant capital outlays over the coming years to both remedy safety concerns and build new capacity for multiple modes of transportation,[9] a major revision to the existing bridge classification, E 2103, is both timely and appropriate. At the October 2009 ASTM E06.81 meeting, a motion was passed to completely revise and restructure E 2103 to be fully consistent with the UNIFORMAT II Guidelines document. Plans for revising and restructuring E 2103 were presented at the April 2010 and October 2010 ASTM E06.81 meetings. This report expands on those plans by providing an in-depth description of what the restructured version of E 2103 will include to bring it into full compliance with the UNIFORMAT II Guidelines document. Two major extensions to the proposed UNIFORMAT II classification of bridge elements are also presented. Once approved and reissued by ASTM, the UNIFORMAT II Standard Classification of Bridge Elements, E 2103, will provide the basis for a comprehensive data set of bridge-

[5] Robert P. Charette and Harold E. Marshall. 1999. *UNIFORMAT II: Elemental Classification for Building Specifications, Cost Estimating, and Cost Analysis*, NISTIR 6389. Gaithersburg, MD: National Institute of Standards and Technology.

[6] ASTM International. "Classification of Bridge Elements and Related Approach Work," E 2103, *Annual Book of ASTM Standards: 2010*, Vol. 4.12. West Conshohocken, PA: ASTM International.

[7] ASTM International. "Guidelines for Developing UNIFORMAT II Standard Classifications," Working Paper. West Conshohocken, PA: ASTM International.

[8] http://www.astm.org/COMMIT/SUBCOMMIT/E0681.htm (accessed December 2010).

[9] *ASCE 2009 Report Card for America's Infrastructure*. http://www.infrastructurereportcard.org/ (accessed December 2010).

related costs that will enable public and private decision makers to choose more cost-effective solutions for the design and construction of new bridges and the maintenance and repair of existing bridges across the Nation.

1.2 Purpose

The purpose of this report is threefold. First and foremost, it presents a proposed UNIFORMAT II classification of bridge elements. The proposed classification represents a major revision and restructuring of ASTM Standard Classification E 2103 first issued in 2000 and reissued in 2006. The original bridge classification, E 2103, differed from the UNIFORMAT II elemental classification hierarchy in several ways which limited its applicability. The proposed major revision and restructuring presented in this report is fully consistent with the UNIFORMAT II Guidelines document established by the ASTM E06.81 Subcommittee on Building Economics. These major revisions to E 2103 will promote its relevance, understanding, and acceptance in the bridge industry.

Second, this report includes a set of alphanumeric designators for the proposed multi-level bridge classification. Because many users are interested in constructing databases for use in cost analyses associated with project planning, design, construction, maintenance and repair, and condition assessment, alphanumeric designators provide the basis for compiling, organizing, and referencing cost data. Having a common set of alphanumeric designators promotes consistency in use among the key project participants and other stakeholders associated with the design, construction, and use of bridges and other constructed entities.

Third, this report includes a proposed list of sub-elements for bridges. As noted earlier, the primary focus of the UNIFORMAT II Standard Classification E 1557 and its associated family is on the elemental concept. The UNIFORMAT II hierarchy consists of three levels: Level 1, Major Group Elements; Level 2, Group Elements; and Level 3, Individual Elements. Thus, the core concept of an element resides at Level 3. All three levels are treated in detail in the body of this report and are intended to serve as the basis for the proposed revisions to E 2103. However, because elements—Level 3 in a UNIFORMAT II hierarchy—are major components of a constructed entity (e.g., a bridge), there is often ambiguity of what exactly is included in an Individual Element and what should be rightfully excluded from it. By providing a proposed set of sub-elements as an appendix, this report lays the framework for evaluating the merits of including such a list in E 2103 along with the other proposed revisions discussed in the body of the text. Because sub-elements can be tied into a work breakdown structure, they significantly enhance the usefulness of an elemental classification across all project participants throughout the lifecycle of bridges and other constructed entities.

1.3 Scope and Approach

The report consists of two chapters and three appendices in addition to the Introduction. Chapter 2 presents the proposed UNIFORMAT II classification of bridge elements. The chapter first discusses the rationale for undertaking a major revision of the original E 2103 bridge classification to make it consistent with the UNIFORMAT II Guidelines document established by the ASTM E06.81 Subcommittee on Building Economics. The potential uses of the proposed bridge classification are then discussed. The proposed bridge classification is then described and summarized as a hierarchy with three levels: Level 1, Major Group Elements; Level 2, Group Elements; and Level 3, Individual Elements. The chapter concludes with an element-by-element description of the proposed bridge classification.

Chapter 3 provides a summary and recommendations for further research. Specifically, four additional UNIFORMAT II classifications are proposed for development: (1) tunnels; (2) highways; (3) railroads; and (4) water treatment and distribution. Each of these classifications corresponds to a critical infrastructure need identified in the American Society of Civil Engineers *Report Card for America's Infrastructure*.[10]

Appendix A presents suggested sub-classifications of bridge elements. The sub-classifications expand the Level 3 Individual Elements into their constituent parts. These constituent parts include a Level 4 for all Individual Elements and, where necessary, a Level 5 (i.e., subdivisions of Level 4).

Appendix B is designed as an illustrated guide to the proposed UNIFORMAT II classification of bridge elements. The appendix includes diagrams, engineering drawings, and, where appropriate, photographs to identify the appearance of each element and how it fits into the overall framework.

Appendix C uses a case study bridge construction project to demonstrate how to use the proposed UNIFORMAT II classification and sub-classifications to analyze and manage bridge design and construction costs. The bridge is a single-span, modified tied-arch carrying Interstate 94 (I-94) over Telegraph Road in Taylor, Michigan. This bridge was part of the reconstruction of I-94 for the Super Bowl XL game held in 2006.

[10] *ASCE 2009 Report Card for America's Infrastructure*, *op cit*.

2 Proposed UNIFORMAT II Classification of Bridge Elements

2.1 Rationale for Classification

The Engineering Laboratory at NIST has launched the Automated and Integrated Infrastructure Construction Processes Program to investigate the challenges and evolving technologies needed to enable the construction industry to develop best practices, protocols, and standards to achieve breakthrough improvements in construction productivity and the delivery of physical infrastructure. The timely and cost effective delivery of physical infrastructure is a critical national need. The ASCE *Report Card for America's Infrastructure* highlights the need for maintaining a robust infrastructure to promote the Nation's current standard of living and to advance its competitiveness. Unfortunately, much of the Nation's physical infrastructure is nearing the end of its service life and needs to be repaired or replaced. ASCE estimates the cost of renewing existing, critical infrastructure to be $2.2 trillion.[11]

Bridges are an important part of the Nation's physical infrastructure. Although bridges are usually built to last 50 years, AASHTO estimates that the average bridge in the USA is 43 years old.[12] More than 26 %, or one in four, of the Nation's 609 905 bridges are either structurally deficient or functionally obsolete. A $17 billion annual investment is needed to substantially improve current bridge conditions. Currently, only $10.5 billion is spent annually on the construction and maintenance of bridges.[13]

In response to this challenge, this report presents a proposed classification of bridge elements within the UNIFORMAT II family of elemental classifications that covers most highway bridges, railroad bridges, and pedestrian bridges. The proposed classification represents a major revision and restructuring of ASTM Standard Classification E 2103,[14] a bridge-related standard classification first issued by ASTM in 2000. The original bridge classification, E 2103, differed from the UNIFORMAT II elemental classification hierarchy[15] in several ways which limited its applicability. The major revisions to E 2103 described in this chapter will promote its relevance, understanding, and acceptance in the bridge industry. Once approved and reissued by ASTM, the UNIFORMAT II Standard Classification of Bridge Elements, E 2103, will provide the basis for a comprehensive data set of bridge-related costs that will enable public and private decision makers to choose more cost-effective solutions for the design and construction of new bridges and the maintenance and repair of existing bridges across the Nation.

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[11] *ASCE 2009 Report Card for America's Infrastructure*, *op cit.*
[12] American Association of State Highway and Transportation Officials (AASHTO). 2008. *Bridging the Gap*. Washington, DC: AASHTO.
[13] American Society of Civil Engineers. 2009. *Facts About Bridges*.
[14] ASTM International. E 2103, "Classification of Bridge Elements and Related Approach Work," *op cit*.
[15] ASTM International. E 1557, "Classification of Building Elements and Related Sitework—UNIFORMAT II," *op cit*.

UNIFORMAT II classifications have an elemental format similar to the original UNIFORMAT[16] building elemental classification. However, the title UNIFORMAT II differs from the original in that it now takes into consideration a wide range of constructed entities that collectively form the "Built Environment." Elements, as defined here, are major physical components that are common within constructed entities. Elements perform their given function(s), regardless of the design specification, construction method, or materials used. This proposed elemental classification serves as a consistent reference for analysis, evaluation, and monitoring during the feasibility, planning, and design stages when constructing bridges.

Using the UNIFORMAT II Guidelines document[17] to develop elemental classifications ensures a consistency in the economic evaluation of construction projects over time and from project to project. UNIFORMAT II classifications also enhance reporting at all stages of a constructed entity's life cycle—from feasibility and planning through the preparation of working documents, construction, maintenance, rehabilitation, and disposal.

2.2 How the Proposed Classification will be Used

The proposed UNIFORMAT II classification presented in this report describes bridge elements that are major components of most highway, railroad, and pedestrian bridges. This section covers both the potential users of the proposed UNIFORMAT II classification of bridge elements and the various ways in which the proposed classification can be used to promote more cost-effective bridges throughout their lifecycle.[18] The elemental classification is the common thread linking activities and participants in a bridge project from initial planning through operations, maintenance, and disposal.

As the proposed UNIFORMAT II classification of bridge elements refers solely to permanent, physical parts of any bridge construction, two ASTM Standard Classifications, E 2083[19] and E 2168,[20] need to be included when calculating construction cost. These standards provide for the inclusion of construction enabling, temporary, and risk mitigation cost figures. Procedures for reporting all these figures are

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[16] The original UNIFORMAT classification was developed jointly by the General Services Administration (GSA) and the American Institute of Architects (AIA).

[17] ASTM International. "Guidelines for Developing UNIFORMAT II Standard Classifications," *op cit*.

[18] For additional information on the uses of ASTM Standard Classification E 1557, see Bowen, Charette, and Marshall, *UNIFORMAT II—A Recommended Classification for Building Elements and Related Sitework*, NIST Special Publication 841, *op cit*, and Charette and Marshall, *UNIFORMAT II Elemental Classification for Building Specifications, Cost Estimating, and Cost Analysis*, NISTIR 6389, *op cit*.

[19] ASTM International. "Classification for Building Construction Field Requirements, and Office Overhead and Profit," E 2083, *Annual Book of ASTM Standards: 2010*, Vol. 4.11. West Conshohocken, PA: ASTM International.

[20] ASTM International. "Classification for Allowance, Contingency and Reserve Sums in Building Construction Estimating," E 2168, *Annual Book of ASTM Standards: 2010*, Vol. 4.12. West Conshohocken, PA: ASTM International.

described in ASTM standards E 1804,[21] E 2514,[22] and E 2516.[23] While these three latter standards were primarily written for building construction, they are nonetheless appropriate and readily applied to other forms of construction as well.

Users of the Proposed UNIFORMAT II Classification of Bridge Elements

Financial and Investment—Typically owners, developers, bankers, lenders, accountants, and financial managers.

Implementation—Primarily project managers; facilities programmers; designers, including engineers; and project controls specialists, including cost planners, estimators, schedulers, specification writers, and risk analysts.

Facilities Management—Comprising property portfolio managers, operating staff, and maintenance staff.

Others—Public officials, manufacturers, educators, students, and other project stakeholders.

Applications of the Proposed UNIFORMAT II Classification of Bridge Elements

Financing and Investing—Structuring costs on an elemental basis for economic evaluations (ASTM Standard Practices E 917,[24] E 964,[25] E 1057,[26] E 1074,[27] E 1121,[28] and E 1804[29]) early in the design process helps reduce the cost of early financial analysis

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[21] ASTM International. "Practice for Performing and Reporting Cost Analysis During the Design Phase of a Project," E 1804, *Annual Book of ASTM Standards: 2010*, Vol. 4.11. West Conshohocken, PA: ASTM International.

[22] ASTM International. "Practice for Presentation Format of Elemental Cost Estimates, Summaries, and Analyses," E 2514, *Annual Book of ASTM Standards: 2010*, Vol. 4.12. West Conshohocken, PA: ASTM International.

[23] ASTM International. "Classification for Cost Estimate Classification System," E 2516, *Annual Book of ASTM Standards: 2010*, Vol. 4.12. West Conshohocken, PA: ASTM International.

[24] ASTM International. "Practice for Measuring Life-Cycle Costs of Buildings and Building Systems," E 917, *Annual Book of ASTM Standards: 2010*, Vol. 4.11. West Conshohocken, PA: ASTM International.

[25] ASTM International. "Practice for Measuring Benefit-to-Cost and Savings-to-Investment Ratios for Buildings and Building Systems," E 964, *Annual Book of ASTM Standards: 2010*, Vol. 4.11. West Conshohocken, PA: ASTM International.

[26] ASTM International. "Practice for Measuring Internal Rate of Return and Adjusted Internal Rate of Return for Investments in Buildings and Building Systems," E 1057, *Annual Book of ASTM Standards: 2010*, Vol. 4.11. West Conshohocken, PA: ASTM International.

[27] ASTM International. "Practice for Measuring Net Benefits and Net Savings for Investments in Buildings and Building Systems," E 1074, *Annual Book of ASTM Standards: 2010*, Vol. 4.11. West Conshohocken, PA: ASTM International.

[28] ASTM International. "Practice for Measuring Payback for Investments in Buildings and Building Systems," E 1121, *Annual Book of ASTM Standards: 2010*, Vol. 4.11. West Conshohocken, PA: ASTM International.

[29] ASTM International. "Practice for Performing and Reporting Cost Analysis During the Design Phase of a Project," E 1804, *op cit*.

and can contribute to substantial design and operational savings before decisions have been made that limit options for potential savings.

Cost Modeling, Cost Planning, Estimating and Controlling Project Time and Cost During Planning, Design, and Construction—Use the bridge UNIFORMAT II classification to prepare budgets and to establish elemental cost plans before design begins. Project managers and project controls specialists use these cost plans against which to measure and control project cost, and quality, and to set design-to-cost targets.

Conducting Value Engineering Workshops—Conducting value engineering workshops (ASTM Standard Practices E 1699[30] and E 2013[31]). Use this classification as a checklist to ensure that alternatives for all elements of significant cost in the bridge project are analyzed in the creativity phase of the job plan. Also, use the elemental cost data to expedite the development of cost models for bridge systems.

Developing Initial Project Master Schedules—Since projects are essentially built element by element, UNIFORMAT II classifications are an appropriate basis for preparing construction schedules at the start of the design process. Project managers and project controls specialists use these time plans against which to measure and control project time (ASTM Standard Practice E 2691[32]), prepare detailed project schedules, and to set milestone target dates.

Performing Risk Analyses—Simulation (ASTM Standard Guides E 1369[33] and E 2506[34]) is one technique for developing probability distributions of bridge costs when evaluating the economic risk in undertaking a bridge project. Use individual elements and group elements in this classification for developing probability distributions of elemental costs. From these distributions, build up probability distributions of total costs to establish project contingencies (ASTM Standard Practice E 1946[35] and ASTM Standard Classification E 2168[36]) or to serve as inputs to an economic analysis.

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[30] ASTM International. "Practice for Performing Value Analysis (VA) of Buildings and Building Systems," E 1699, *Annual Book of ASTM Standards: 2010*, Vol. 4.11. West Conshohocken, PA: ASTM International.
[31] ASTM International. "Practice for Constructing FAST Diagrams and Performing Function Analysis During Value Analysis Study," E 2013, *Annual Book of ASTM Standards: 2010*, Vol. 4.11. West Conshohocken, PA: ASTM International.
[32] ASTM International. "Practice for Job Productivity Measurement," E 2691, *Annual Book of ASTM Standards: 2010*, Vol. 4.12. West Conshohocken, PA: ASTM International.
[33] ASTM International. "Guide for Selecting Techniques for Treating Uncertainty and Risk in the Economic Evaluation of Buildings and Building Systems," E 1369, *Annual Book of ASTM Standards: 2010*, Vol. 4.11. West Conshohocken, PA: ASTM International.
[34] ASTM International. "Guide for Developing a Cost-Effective Risk Mitigation Plan for New and Existing Constructed Facilities," E 2506, *Annual Book of ASTM Standards: 2010*, Vol. 4.12. West Conshohocken, PA: ASTM International.
[35] ASTM International. "Practice for Measuring Cost Risk of Buildings and Building Systems," E 1946, *Annual Book of ASTM Standards: 2010*, Vol. 4.11. West Conshohocken, PA: ASTM International.
[36] ASTM International. "Classification for Allowance, Contingency and Reserve Sums in Building Construction Estimating," E 2168, *op cit.*

Structuring Preliminary Project Descriptions During the Conceptual Design Phase—This classification facilitates the description of the scope of the project in a clear, concise, and logical sequence for presentation to the client; it provides the basis for the preparation of more detailed elemental estimates during the early concept and preliminary design phases, and it enhances communication between designers and clients by providing a clear statement of the designer's intent.

Coding and Referencing Standard Details In Computer-Aided Design Systems—This classification allows a designer, for example, to reference an assembly according to this classification's element designations and build up a database of standard details. This is particularly appropriate to design modeling and building information modeling (BIM) applications.

Managing Facilities—Recording and writing property condition assessment reports in a structured way, using UNIFORMAT II classifications, provides for a consistent, accessible, and searchable database of real property inventory.

Other Activities—Structuring cost manuals and recording construction, operating, and maintenance costs in a computer database. Having a cost manual or computer database in an elemental format assists the preparation of an economic analysis early in the design stage and at a reasonable cost.

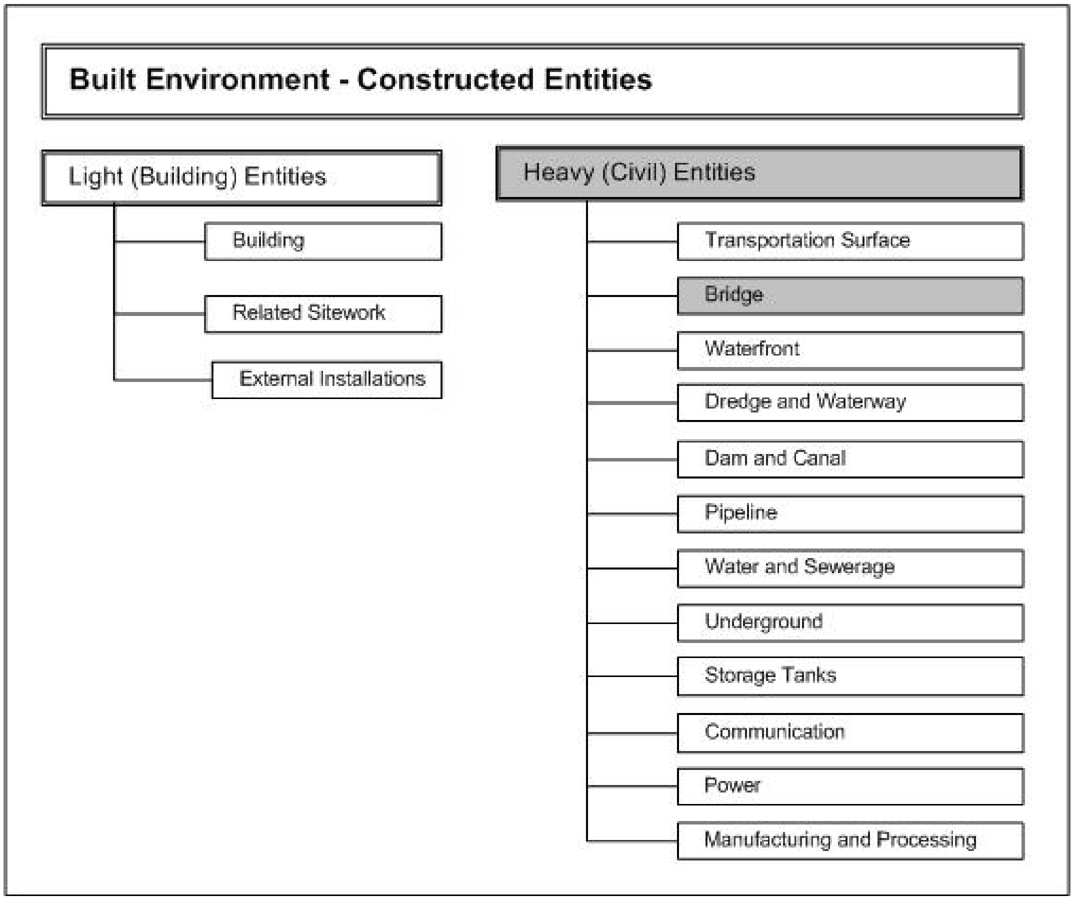
2.3 Basis of Classification

The framework in Table 2.1 shows the two branches that serve to define the built environment—light construction associated with buildings and heavy construction associated with civil structures. Under each branch are listed, the various constructed entities that collectively are used to create the built environment. Each entity is treated as a module, where a module may result in one or more UNIFORMAT II elemental classifications. Appropriate modules, and the standards associated with them, when used together will effectively describe any planned or built development.

The proposed classification covered in this report describes exclusively the elements that make up one of those constructed entities, bridge structures, shown as the shaded block under the heading of Heavy (Civil) Entities. ***This bridge classification is applicable to most types of highway, railroad, and pedestrian bridges.***

> ***The classification includes: slab bridges; beam/girder bridges; truss bridges; true and tied-arch bridges; cable-stayed bridges; and suspension bridges.***
>
> ***The classification does not include the following movable bridge types: draw bridges; lift bridges; and bascule bridges.***

Table 2.1 List of Constructed Entities Suitable for Inclusion in the Family of UNIFORMAT II Elemental Classifications



The proposed UNIFORMAT II bridge classification is consistent with typical costing practices used at the conceptual design phase. Each element has a significant impact on the cost, and it usually occurs frequently. Each element performs a specific function.

Table 2.2 divides the classification of bridge elements into three hierarchical levels: Level 1, Major Group Elements; Level 2, Group Elements; and Level 3, Individual Elements. The Major Groups are listed in the normal chronological order of construction. The proposed UNIFORMAT II bridge classification builds on the concepts and organizational framework put forth in the E 1557 standard classification.

Table 2.2 Proposed UNIFORMAT II Classification of Bridge Elements

Level 1 Major Group Elements	Level 2 Group Elements	Level 3 Individual Elements
A Substructure	A10 Piers	A1010 Foundations A1020 Walls A1030 Columns A1040 Cap Beams
	A20 Towers	A2010 Foundations A2020 Walls A2030 Columns A2040 Cap Beams
	A30 Abutments	A3010 Foundations A3020 Stems A3030 Wing Walls
	A40 Other Supports	A4010 Thrust Blocks A4020 Anchorages
B Superstructure	B10 Short Span Assemblies	B1010 Flexural Members B1020 Diaphragms B1030 Bracings B1040 Bearings
	B20 Long Span Assemblies	B2010 Ribs B2020 Cables B2030 Hangers B2040 Spandrels B2050 Ties B2060 Truss Members B2070 Segmental Box Girders
	B30 Deck	B3010 Structural Surface B3020 Wearing Surface
C Protection	C10 Structure Protection	C1010 Slope Walls C1020 Expansion Joints C1030 Protective Coats C1040 Sacrificial Beams C1050 Drainage Systems C1060 Inspection and Maintenance Systems
	C20 Traffic Protection	C2010 Barriers C2020 Protective Shields C2030 Traffic Controls
	C30 Other Protection	C3010 Lighting C3020 Signage C3030 Sound Barrier Walls C3040 Air Pressure Barriers C3050 Enclosure
D Sitework	D10 Site Preparation	D1010 Clearing and Grubbing D1020 Demolition and Relocation D1030 Earthwork D1040 Hazardous Material Handling D1050 Environmental Restoration/Replacement
	D20 Approach Construction	D2010 Approach Slabs D2020 Sleeper Slabs D2030 Earth Retention Systems

Sub-Classifications (see Appendix A) are named Sub-Elements and comprise as many hierarchical levels (Level 4 and below) as are deemed appropriate to the needs of that specific example.

The decision as to where among the classification elements to include specific construction items will rely on professional judgment as to where professionals in current practice normally look for such items.

Only items that impact the choice and cost of the bridge elements are included. Other civil works in the transportation system are not included. ***Consequently, the proposed classification does not include utilities—pipelines (water, natural gas, and petroleum) and transmission lines (electrical, communication, and video)—sharing the same right of way as the transportation system.***

Elements, as used and defined in the UNIFORMAT II family of classifications, will ideally display the following additional attributes:

Capable of being defined precisely;

Self-explanatory;

Separable at all stages of development;

Quantifiable at all stages of development;

Capable of reconciliation with other elemental classifications;

Allow comparisons, project to project, in a meaningful way;

Is a functional component of the constructed entity.

Sitework elements are provided in the proposed classification for exclusive use in support of the construction of bridges, not to classify elements of major civil construction works. Sitework elements presented in Table 2.2 are designed to provide sufficient detail to planners so they will not need to resort to other elemental classifications when working on a bridge project.

2.4 Description of Proposed UNIFORMAT II Bridge Elements

Table 2.3 provides, for each Level 3 Individual Element, the name, functions, description, inclusions, exclusions, and unit of measure. The table uses the framework outlined in the UNIFORMAT II Guidelines document.[37] The goal of that framework is to briefly, yet concisely, summarize the important features of each element. As a complement to the material presented in this section, this report includes Appendix B and Appendix C to facilitate the use of the proposed UNIFORMAT II classification of bridge elements.

[37] ASTM International. “Guidelines for Developing UNIFORMAT II Standard Classifications,” *op cit*.

Appendix B is designed as an illustrated guide to the proposed UNIFORMAT II classification of bridge elements. The appendix includes diagrams, engineering drawings, and, where appropriate, photographs to identify the appearance of each element and how it fits into the overall framework.

Appendix C uses a case study bridge construction project to demonstrate how to use the proposed UNIFORMAT II classification and sub-classifications to analyze and manage bridge design and construction costs. The case study bridge is a single-span, modified tied-arch carrying Interstate 94 (I-94) over Telegraph Road in Taylor, Michigan. This bridge was part of the reconstruction of I-94 for the Super Bowl XL game held in 2006.

The functions are classified as Primary, Secondary, and Tertiary. All three levels of functions may be served. However, one or two functions may be the driving force behind the existence of the element, and they are classified as Primary functions.

The element descriptions provide an understanding of the purpose and application of the element. The narrative is intended to provide a brief synopsis of the key features which serve to define the element.

The purpose of the element inclusions is to list features that make up the element.

The purpose of the element exclusions is to list features that are not included in the element but which are included elsewhere in the proposed classification. ***Because this classification refers solely to permanent physical parts of bridge constructions, references to construction enabling (cranes and formwork), temporary construction (cofferdams and traffic detours), and risk mitigation (allowances and contingencies) cost figures are omitted from the element exclusions.***[38]

The purpose of the unit of measure is to provide a means for calculating the magnitude, or size, of each element in any bridge description; units of measure are important to all users of elemental classifications. Units of measure are of prime importance in the elemental cost management process. Both SI and Customary units are reported. SI units are reported first followed by Customary units within parentheses. Table 2.3 uses the following unit of measure abbreviations: linear meters (m) and linear feet (ft); square meters (m^2) and square feet (ft^2); cubic meters (m^3) and cubic yards (yd^3); and kilograms (kg) and pounds (lb).

[38] Appendix C provides for the inclusion of construction enabling, temporary, and risk mitigation cost figures. Two tables are used to introduce costs related to program management (field requirements and office overhead and profit) and risk management (allowances, contingencies, and reserve sums). Cost data for the Telegraph Road bridge are then tabulated and analyzed using the two tables referenced above and the proposed classification presented in this section and the sub-classifications presented in Appendix A.

Table 2.3 Description of Proposed UNIFORMAT II Bridge Elements

A SUBSTRUCTURE	
A10 Piers	
A1010 Foundations	
Primary Function	Transfer load, Minimize settlement
Secondary Function	Minimize maintenance
Tertiary Function	Facilitate construction
Description	Foundations are structures that transfer the load of the bridge substructures to the ground. They may be spread footings, piles, or drilled shafts. The type depends upon the soil conditions.
Includes	Excavation and backfilling
Excludes	
Unit of Measure	m^3 (yd^3) or m (ft)

A1020 Walls	
Primary Function	Distribute load, Protect foundation
Secondary Function	Enhance appearance
Tertiary Function	Expedite construction
Description	Walls are structures that support and brace the columns; in addition to transferring the load from the columns to the foundation, they protect the pier against impacts from vehicles, vessels, and debris.
Includes	Any struts to brace columns
Excludes	
Unit of Measure	m^3 (yd^3) or kg (lb)

A1030 Columns	
Primary Function	Distribute load
Secondary Function	Enhance appearance
Tertiary Function	Expedite construction
Description	Columns are structures that support the cap beam and transfer the load from the cap beam to the wall below.
Includes	
Excludes	
Unit of Measure	m^3 (yd^3) or kg (lb)

A1040 Cap Beams	
Primary Function	Distribute load
Secondary Function	Enhance appearance
Tertiary Function	Expedite construction
Description	Cap beams are structures that receive and transfer beam loads from the deck to the bridge columns.
Includes	Bridge seat
Excludes	Bearings and anchor bolts (see Bearings, Flexural Members)
Unit of Measure	m^3 (yd^3) or kg (lb)

A SUBSTRUCTURE	
A20 Towers	
A2010 Foundations	
Primary Function	Transfer load, Minimize settlement
Secondary Function	Minimize maintenance
Tertiary Function	Facilitate construction
Description	Foundations are structures that transfer the load of the bridge substructures to the ground. They may be spread footings, piles, or drilled shafts. The type depends upon the soil conditions.
Includes	Excavation and backfilling
Excludes	
Unit of Measure	m^3 (yd^3) or m (ft)

A2020 Walls	
Primary Function	Distribute load, Protect foundation
Secondary Function	Enhance appearance
Tertiary Function	Expedite construction
Description	Walls are structures that support and brace the columns; in addition to transferring the load from the columns to the foundation, they protect the pier against impacts from vehicles, vessels, and debris.
Includes	Any struts to brace columns
Excludes	
Unit of Measure	m^3 (yd^3) or kg (lb)

A2030 Columns	
Primary Function	Distribute load
Secondary Function	Enhance appearance
Tertiary Function	Expedite construction
Description	Columns are structures that support the cap beam and transfer the load from the cap beam to the wall below.
Includes	
Excludes	
Unit of Measure	m^3 (yd^3) or kg (lb)

A2040 Cap Beams	
Primary Function	Distribute load
Secondary Function	Enhance appearance
Tertiary Function	Expedite construction
Description	Cap beams are structures that receive and transfer beam loads from the deck to the bridge columns.
Includes	Bridge seat
Excludes	Bearings and anchor bolts (see Bearings, Flexural Members)
Unit of Measure	m^3 (yd^3) or kg (lb)

A SUBSTRUCTURE	
A30 Abutments	
A3010 Foundations	
Primary Function	Transfer load, Minimize settlement
Secondary Function	Minimize maintenance
Tertiary Function	Facilitate construction
Description	Foundations are structures that transfer the load of the bridge substructures to the ground. They may be spread footings, piles, or drilled shafts. The type depends upon the soil conditions.
Includes	Excavation and backfilling
Excludes	
Unit of Measure	m^3 (yd^3) or m (ft)

A3020 Stems	
Primary Function	Distribute load, Retain earth
Secondary Function	Minimize erosion
Tertiary Function	Minimize settlement
Description	Stems are usually supported on piles; they partially or fully retain earth behind, support the ends of the first and last spans of the bridge, and support the approach slab.
Includes	Bridge seat, reinforcing, concrete, and finishing
Excludes	Slope wall, foundation, drainage, and anchor bolts and bearings (see Foundations, Drainage Systems, Slope Wall, Bearings)
Unit of Measure	m^3 (yd^3) or kg (lb)

A3030 Wing Walls	
Primary Function	Retain earth
Secondary Function	Minimize erosion
Tertiary Function	Enhance appearance
Description	Wing walls (parallel, perpendicular, or angled) are structures connected to the abutment and supported by piles that retain the embankment below the approach road.
Includes	Reinforcing, concrete, and finishing
Excludes	Approach slab and parapet (see Approach Slab, Barriers)
Unit of Measure	m^3 (yd^3)

A SUBSTRUCTURE	
A40 Other Supports	
A4010 Thrust Blocks	
Primary Function	Transfer load, Transfer thrust
Secondary Function	Minimizes movement
Tertiary Function	
Description	Thrust blocks are a special substructure of a true arch bridge that receive loads from the ribs and transfer loads to the foundation.
Includes	Structure excavation, reinforcing, concrete, and finishing
Excludes	Furnishing and installation of anchor bolts, bearing plates, utility relocation (see Demolition and Relocation, Flexural Members)
Unit of Measure	m^3 (yd^3)

A4020 Anchorages	
Primary Function	Secure cable, Transfer load
Secondary Function	Maintain even distribution
Tertiary Function	
Description	Anchorages are a special substructure to which the weight of the deck and supporting superstructure is secured via cables and steel eye bars imbedded in solid rock or massive concrete blocks.
Includes	Structure excavation, reinforcing, concrete, finishing, and cable support (Steel Eye Bar)
Excludes	
Unit of Measure	m^3 (yd^3)

B SUPERSTRUCTURE	
B10 Short Span Assemblies	
B1010 Flexural Members	
Primary Function	Support Load
Secondary Function	Minimize deflection
Tertiary Function	Increase redundancy
Description	Flexural members are commonly known as beams and girders that support the bridge deck. When the depth of the girder is shallow, it is referred to as a beam.
Includes	Fabrication and installation of beams, girders, shear connectors, splices, connections, and stiffeners
Excludes	Diaphragms, bracings, bearings (see Diaphragms, Bracings, Bearings)
Unit of Measure	kg (lb) or m (ft)

B1020 Diaphragms	
Primary Function	Stabilize girder, Brace girders
Secondary Function	Facilitate deck reconstruction
Tertiary Function	
Description	Diaphragms are braces for shallow-depth beams.
Includes	
Excludes	
Unit of Measure	kg (lb) or m^3 (yd^3)

B1030 Bracings	
Primary Function	Stabilize girders/ribs/truss members
Secondary Function	Facilitate deck reconstruction
Tertiary Function	
Description	Bracings are structural members used to brace deep-depth girders, ribs, and truss members.
Includes	Fabrication and erection of structural members
Excludes	
Unit of Measure	kg (lb)

B1040 Bearings	
Primary Function	Transfer load
Secondary Function	Facilitate expansion and contraction
Tertiary Function	Minimize maintenance
Description	Bearings are mechanical systems that transfer vertical and longitudinal forces; expansion bearings allow rotational and longitudinal movement.
Includes	Fabrication and erection of bearings and anchor bolts
Excludes	Bridge seat (see Cap Beams, Stems)
Unit of Measure	EACH

B SUPERSTRUCTURE	
B20 Long Span Assemblies	
B2010 Ribs	
Primary Function	Transfer load
Secondary Function	Facilitate inspection
Tertiary Function	Enhance appearance
Description	Ribs are rectangular-, square-, or circular-shaped parts of the superstructure for arch bridges; they receive loads from hangers and spandrels and transfer them to the foundation.
Includes	Splices, stiffeners, and special assemblies
Excludes	Bracings, bearings (see Bracings, Bearings)
Unit of Measure	kg (lb), or m^3 (yd^3), or m (ft)

B2020 Cables	
Primary Function	Transfer load
Secondary Function	Enhance appearance
Tertiary Function	
Description	Cables, made of steel wires bound together and draped over towers to anchors at each cable end, receive through hangers the load from the deck.
Includes	Fabrication and installation of cables, cable support
Excludes	Anchorage (see Anchorage)
Unit of Measure	m (ft)

B2030 Hangers	
Primary Function	Transfer load
Secondary Function	Ease replacement
Tertiary Function	Enhance appearance
Description	Hangers are rods or strands that connect the deck to the ribs (arch bridges) or the main cable (cable-stayed or suspension bridges); they receive loads from the deck and transfer loads to the ribs or main cable in tension.
Includes	Splices (rod), strand assembly, protection
Excludes	End connections (see Flexural Members and Ribs)
Unit of Measure	m (ft)

B2040 Spandrels	
Primary Function	Transfer load
Secondary Function	Ease replacement
Tertiary Function	Enhance appearance
Description	Spandrels are concrete or steel members that connect the deck to the ribs (arch bridges); they receive loads from the deck and transfer loads to the ribs in compression. They are below the deck and above the rib.
Includes	Concrete or steel members, protection
Excludes	End connections (see Flexural Members and Ribs)
Unit of Measure	m (ft)

B2050 Ties	
Primary Function	Eliminate thrust
Secondary Function	
Tertiary Function	
Description	A tie is a horizontal tension member that connects the two ends of the compression ribs of an arch bridge and balances the horizontal thrust.
Includes	Fabrication and erection of structural steel, stiffeners, splices, and other connections
Excludes	Hangers, spandrels, bearings (see Bearings, Hangers, and Spandrels)
Unit of Measure	kg (lb)

B2060 Truss Members	
Primary Function	Support load, Reduce weight
Secondary Function	Minimize deflection
Tertiary Function	
Description	Truss members, connected at nodes by plates, are two-dimensional structures that support the superstructure.
Includes	Splices and other connections
Excludes	Bracings, bearings (see Bracings, Bearings)
Unit of Measure	kg (lb), or m^3 (yd^3), or m (ft)

B2070 Segmental Box Girders	
Primary Function	Support Load
Secondary Function	Minimize deflection
Tertiary Function	Facilitate Construction
Description	Segmental box girders are concrete box sections with or without overhanging flanges. The segments are precast sections which are post tensioned in the field.
Includes	Post tensioning
Excludes	Bracings, bearings (see Bracings, Bearings)
Unit of Measure	m (ft)

B SUPERSTRUCTURE	
B30 Deck	
B3010 Structural Surface	
Primary Function	Transfer load
Secondary Function	Minimize maintenance
Tertiary Function	Facilitate future expansion
Description	The structural surface supports the wearing surface and traffic.
Includes	Reinforcing, concrete, and finishing
Excludes	Expansion joint assembly, parapet, barriers (see Expansion Joints, Barriers, Drainage)
Unit of Measure	m^3 (yd^3) or EACH

B3020 Wearing Surface	
Primary Function	Protect structure, Guide traffic
Secondary Function	Comfort riders
Tertiary Function	Reduce maintenance
Description	The wearing surface is the part of the road or rail system that comes into contact with the vehicle or train car wheels.
Includes	Concrete or asphalt overlay or rails, striping, and marking
Excludes	
Unit of Measure	m^2 (ft^2)

C PROTECTION	
C10 Structure Protection	
C1010 Slope Walls	
Primary Function	Protect abutment
Secondary Function	Prevent erosion
Tertiary Function	Enhance appearance
Description	Slope walls, made of stone, concrete, gravel, or gravel with asphalt mix, support the sloped surface and protect the bridge abutment.
Includes	Reinforcing, concrete, and finishing
Excludes	Excavation and backfill (see Earthwork)
Unit of Measure	m^2 (ft^2)

C1020 Expansion Joints	
Primary Function	Facilitate expansion and contraction
Secondary Function	Maintain smooth surface
Tertiary Function	Facilitate replacement
Description	Expansion joints allow expansion and contraction of the slab while keeping the substructure stationary.
Includes	Furnishing and installation of expansion joint support and expansion joint
Excludes	
Unit of Measure	m (ft)

C1030 Protective Coats	
Primary Function	Protect structure
Secondary Function	Minimize maintenance
Tertiary Function	
Description	Protective coats are paints, sealants, or preservatives that are applied to concrete surfaces of the bridge.
Includes	Minor repair work, cleaning surface, and coating
Excludes	Major repair work to other bridge elements
Unit of Measure	m^2 (ft^2)

C1040 Sacrificial Beams	
Primary Function	Protect girders
Secondary Function	Reduce maintenance
Tertiary Function	
Description	Sacrificial beams have a lower clearance than the main beams to ensure that excessive-height vehicles will hit the sacrificial beam before impacting the main beams.
Includes	Fabrication and erection of structural steel, stiffeners, splices, and other connections
Excludes	Bracings, bearings (see Bracings, Bearings)
Unit of Measure	kg (lb)

C1050 Drainage Systems	
Primary Function	Minimize erosion
Secondary Function	Protect traffic
Tertiary Function	Protect structure
Description	Drainage systems are scuppers to drain the bridge deck, downspouts to carry off the water from the scuppers, and buried drains behind abutments and adjacent to sleeper slabs.
Includes	Fabrication and installation of scuppers, drain tiles, drain pipes, and related earthwork
Excludes	Structural surface (see Structural Surface)
Unit of Measure	EACH or m (ft)

C1060 Inspection and Maintenance Systems	
Primary Function	Facilitate inspection
Secondary Function	Facilitate maintenance
Tertiary Function	
Description	These systems include platforms, railings, stairways, and hoist ways to facilitate inspection and maintenance.
Includes	Handrails or other type of barriers
Excludes	
Unit of Measure	m^2 (ft^2)

C PROTECTION	
C20 Traffic Protection	
C2010 Barriers	
Primary Function	Separate traffic, Protect occupants
Secondary Function	Protect structure
Tertiary Function	Minimize maintenance
Description	Barriers are structures designed to: withstand forces due to crashes; separate the opposing traffic; and protect bridge structures adjacent to live traffic.
Includes	Noise wall support, light pole support, traffic control support
Excludes	
Unit of Measure	m^3 (yd^3)

C2020 Protective Shields	
Primary Function	Protect traffic (below)
Secondary Function	
Tertiary Function	
Description	Protective shields are barriers below the bridge deck to protect traffic below from falling objects.
Includes	Membranes and supports designed to catch falling objects
Excludes	
Unit of Measure	m^2 (ft^2)

C2030 Traffic Controls	
Primary Function	Manage Traffic
Secondary Function	
Tertiary Function	
Description	Traffic controls are an assembly of signals, supports, and conduits
Includes	Power source and related items
Excludes	Base Support (see Barriers)
Unit of Measure	EACH

C PROTECTION	
C30 Other Protection	
C3010 Lighting	
Primary Function	Protect traffic
Secondary Function	Guide traffic
Tertiary Function	Discourage vandalism
Description	Lighting is illumination from fixtures that provide vehicle traffic direction, ship navigation direction, task lighting, and vandalism discouragement.
Includes	Fabrication and installation of mast, lights, base plates, and power
Excludes	Base support (see Barriers)
Unit of Measure	EACH

C3020 Signage	
Primary Function	Guide traffic
Secondary Function	Simplify or consolidate message
Tertiary Function	
Description	Signage is the provision of information through electronic or printed message boards.
Includes	Fabrication and installation of sign and support, and power
Excludes	
Unit of Measure	EACH

C3030 Sound Barrier Walls	
Primary Function	Abate traffic noise
Secondary Function	Create visual barrier
Tertiary Function	Enhance appearance
Description	A sound barrier wall is a structure to mask traffic noise from the surrounding neighborhood.
Includes	Wall panel, support, and connection to barrier
Excludes	Base (see Barriers)
Unit of Measure	m^2 (ft^2)

C3040 Air Pressure Barriers	
Primary Function	Protect people
Secondary Function	Protect property
Tertiary Function	
Description	Air pressure barriers are structures to mitigate the impact of significant air pressure differentials created by the passing of high speed transportation vehicles.
Includes	Barriers mounted on bridges to mitigate the impact of air pressure differentials.
Excludes	Base (see Barriers)
Unit of Measure	m^2 (ft^2)

C3050 Enclosure	
Primary Function	Protect pedestrians and protect traffic
Secondary Function	Facilitate maintenance
Tertiary Function	Enhance appearance
Description	An enclosure is a vertical envelope with roof to protect pedestrians and traffic crossing over a bridge.
Includes	Structural and architectural members to contain pedestrians and traffic.
Excludes	
Unit of Measure	m^2 (ft^2)

D SITEWORK	
D10 Site Preparation	
D1010 Clearing and Grubbing	
Primary Function	Eliminate obstacles
Secondary Function	Create staging area
Tertiary Function	Provide temporary drainage
Description	Clearing is the removal from the construction site of trees and abandoned utilities, and the grading and leveling of the site. Grubbing is the removal of stumps and tree roots.
Includes	Tree removal, abandoned utilities, minor earthwork
Excludes	Major earth work and major utility removal (see Demolition and Relocation, Earthwork)
Unit of Measure	EACH or Hectare (Acre)

D1020 Demolition and Relocation	
Primary Function	Eliminate obstacles
Secondary Function	Protect structures
Tertiary Function	Protect environment
Description	Demolition is the complete or partial (e.g., deck or superstructure) removal of an existing bridge, carried out on the whole bridge at once or by removing a portion of the deck or superstructure in stages to maintain traffic; relocation is the removal and reinstallation of utilities.
Includes	Removal of bridge elements and disposal, relocation of utilities such as storm sewer
Excludes	
Unit of Measure	EACH

D1030 Earthwork	
Primary Function	Prepare grade
Secondary Function	Protect structures
Tertiary Function	Protect environment
Description	Earthwork is excavation, placement, and compaction of material to raise the bridge profile (material is hauled in and compacted) and to lower the bridge profile (material is excavated and hauled away).
Includes	Shrinkage factor for embankment, hauling material to or from the site
Excludes	Removal of hazardous material, structure excavation and back fill (see Demolition and Relocation, Foundations)
Unit of Measure	m^3 (yd^3)

D1040 Hazardous Material Handling	
Primary Function	Protect environment
Secondary Function	Dispose hazardous waste
Tertiary Function	Protect workers
Description	Hazardous material handling is the discovery, excavation, recovery, and disposal of hazardous materials.
Includes	Excavation and disposal of material
Excludes	General excavation (see Demolition and Relocation, Earthwork)
Unit of Measure	m^3 (yd^3)

D1050 Environmental Restoration/Replacement	
Primary Function	Protect environment
Secondary Function	
Tertiary Function	
Description	Environmental restoration/replacement is the activity of restoring or replacing elements of the environment disturbed by construction.
Includes	Restoration or replacement of wetlands
Excludes	
Unit of Measure	Hectare (Acre)

D SITEWORK	
D20 Approach Construction	
D2010 Approach Slabs	
Primary Function	Provide transition
Secondary Function	Minimize settlement effects
Tertiary Function	Facilitate construction
Description	An approach slab, supported by the bridge abutment on one side and a sleeper slab or soil on the other, provides a smooth transition between the roadway and the bridge, and spans any settlement gap between the abutment and the roadway.
Includes	Concrete, reinforcing, and finishing
Excludes	Barrier and wing wall (see Barriers, Wing Walls)
Unit of Measure	m^2 (ft^2)

D2020 Sleeper Slabs	
Primary Function	Protect substructure
Secondary Function	Exclude water
Tertiary Function	Minimize maintenance
Description	Sleeper slabs are rectangular concrete foundations that support approach slabs.
Includes	Excavation and backfill, concrete, and reinforcing
Excludes	Approach slab (see Approach Slabs)
Unit of Measure	m^3 (yd^3)

D2030 Earth Retention Systems	
Primary Function	Retain embankment
Secondary Function	Enhance appearance
Tertiary Function	Facilitate construction
Description	Earth retention systems are designed to support embankments when the grades are not uniform.
Includes	Foundation, wall, and cap
Excludes	Excavation and backfill (see Earthwork)
Unit of Measure	m^3 (yd^3) or m^2 (ft^2)

3 Summary and Recommendations for Further Research

3.1 Summary

This report presents a proposed UNIFORMAT II classification of bridge elements. Elemental classifications differ from traditional product-related classifications because their core concept is an element that performs a given function, regardless of the design specification, construction method, or materials used. The proposed classification represents a major revision and restructuring of ASTM Standard Classification E 2103, a bridge-related standard classification first issued by ASTM in 2000. The original bridge classification, E 2103, differed from the UNIFORMAT II elemental classification hierarchy in several ways which limited its applicability. The major revisions to E 2103 described in this report will promote its relevance, understanding, and acceptance in the bridge industry. Once approved and reissued by ASTM, the UNIFORMAT II Standard Classification of Bridge Elements, E 2103, will provide the basis for a comprehensive data set of bridge-related costs that will enable public and private decision makers to choose more cost-effective solutions for the design and construction of new bridges and the maintenance and repair of existing bridges across the Nation.

A set of alphanumeric designators for the proposed bridge classification is included. Because many users are interested in constructing databases for use in cost analyses associated with project planning, design, construction, maintenance and repair, and condition assessment, alphanumeric designators provide the basis for compiling and organizing cost data.

This report also includes a proposed list of sub-elements for bridges. The UNIFORMAT II hierarchy consists of three levels: Level 1, Major Group Elements; Level 2, Group Elements; and Level 3, Individual Elements. Thus, the core concept of an element resides at Level 3. However, because elements are major components of a constructed entity, there is often ambiguity of what exactly is included in an Individual Element and what should be rightfully excluded from it. Because sub-elements can be tied into a work breakdown structure, they significantly enhance the usefulness of an elemental classification across all project participants throughout the lifecycle of bridges and other constructed entities.

3.2 Recommendations for Further Research

The background work for this report uncovered several additional areas of research that would be of value to government agencies, standards development organizations, designers and constructors of physical infrastructure projects, and other stakeholders concerned with the costs of designing and constructing new physical infrastructure and of maintaining and repairing existing physical infrastructure across the Nation. Specifically, four additional UNIFORMAT II classifications are proposed for development: (1) tunnels; (2) highways; (3) railroads; and (4) water treatment and distribution. Each of these proposed UNIFORMAT II classifications corresponds to a critical infrastructure need identified in the American Society of Civil Engineers *Report Card for America's Infrastructure*.[39]

[39] *ASCE 2009 Report Card for America's Infrastructure*, *op cit*.

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[40] Diagrams from the *IDOT Bridge Standards* document reproduced in this report were in effect on March 25, 2011; current *IDOT Bridge Standards* are available at: http://www.dot.il.gov/bridges/bscadd2.html.

Appendix A Suggested Sub-Classifications of Bridge Elements

This appendix presents suggested sub-classifications of bridge elements. The sub-classifications expand the Level 3 Individual Elements into their constituent parts. These constituent parts include a Level 4 for all Individual Elements and, where necessary, a Level 5 (i.e., subdivisions of Level 4).

The suggested sub-classifications are presented in Table A.1. Table A.1 is laid out in a six column format. The first column lists the Level 1 Major Group Elements. The second column lists the Level 2 Group Elements. The third column lists the Level 3 Individual Elements. The fourth column lists the Level 4 Sub-Elements associated with each Level 3 Individual Element. The fifth column lists any Level 5 Sub-Elements associated with a Level 4 Sub-Element. Where appropriate, the Level 5 Sub-Elements are listed in the normal chronological order of construction. The sixth column lists any Level 5 Field Requirements that are both significant in their cost and specific to a Level 4 Sub-Element (e.g., Formwork associated with Spread Footings).

Alphanumeric designators are included for all Level 4 Sub-Elements, Level 5 Sub-Elements, and Level 5 Field Requirements. It is anticipated that the alphanumeric designators will be useful in structuring cost manuals and in recording construction, operating, and maintenance costs in computer databases.

The alphanumeric designators use the Level 3 Individual Element character string as their reference point. For example, the first Level 4 Sub-Element associated with the A1010 Foundations Level 3 Individual Element is A101010 Spread Footings. Additional Level 4 Sub-Elements associated with A1010 Foundations are: A101020 Piles and A101030 Drilled Shafts. For Level 5 Sub-Elements, the alphanumeric designator uses the Level 4 Sub-Element as their reference point. For example, the first Level 5 Sub-Element associated with the A101010 Spread Footings Level 4 Sub-Element is A10101010 Excavation. Additional Level 5 Sub-Elements associated with A101010 Spread Footings are: A10101020 Reinforcement; A10101030 Placement; and A10101040 Backfilling. Spread Footings have a significant field requirement associated with them due to Formwork. The alphanumeric designator for Field Requirements includes an X to tie it back to Table 1 in E 2083, Standard Classification for Building Construction Field Requirements and Office Overhead and Profit. For example, the Level 5 Field Requirement associated with the A101010 Spread Footings Level 4 Sub-Element is A101010X2 Formwork. If Spread Footings are installed in a waterway, a Cofferdam will be required before Excavation can commence. In this case, the Level 5 Field Requirement associated with the A101010 Spread Footings Level 4 Sub-Element is A101010X1 Cofferdam.

Table A.1 Suggested Sub-Classifications of Bridge Elements

Level 1 Major Group Elements	Level 2 Group Elements	Level 3 Individual Elements	Level 4 Sub-Elements	Level 5 Sub-Elements	Level 5 Field Requirements
A Substructure	A10 Piers	A1010 Foundations	A101010 Spread Footings		A101010X1 Cofferdam
				A10101010 Excavation	
					A101010X2 Formwork
				A10101020 Reinforcement	
				A10101030 Placement	
				A10101040 Backfilling	
			A101020 Piles	A10102010 Test Piles	
				A10102020 Piles	
				A10102030 Pile Cap	
			A101030 Drilled Shafts		A101030X1 Temporary Casing
				A10103010 Permanent Casing	
				A10103020 Rock Socket	
				A10103030 Bell	
				A10103040 Reinforcement	
				A10103050 Placement	
				A10103060 Cap	
		A1020 Walls	A102010 Cast-in-Place Concrete		A102010X1 Formwork
				A10201020 Reinforcement	
				A10201030 Placement	
				A10201040 Finishing	
				A10201050 Coating	
			A102020 Precast Concrete	A10202010 Fabrication	
				A10202020 Erection	

Level 1 Major Group Elements	Level 2 Group Elements	Level 3 Individual Elements	Level 4 Sub-Elements	Level 5 Sub-Elements	Level 5 Field Requirements
		A1030 Columns	A103010 Cast-in-Place Concrete		A103010X1 Formwork
				A10301020 Reinforcement	
				A10301030 Placement	
				A10301040 Finishing	
			A103020 Precast Concrete	A10302010 Fabrication	
				A10302020 Erection	
			A103030 Steel	A10303010 Fabrication	
				A10303020 Erection	
			A103040 Timber	A10304010 Fabrication	
				A10304020 Erection	
		A1040 Cap Beams	A104010 Cast-in-Place Concrete		A104010X1 Formwork
				A10401020 Reinforcement	
				A10401030 Placement	
				A10401040 Finishing	
			A104020 Precast Concrete	A10402010 Fabrication	
				A10402020 Erection	
			A104030 Steel	A10403010 Fabrication	
				A10403020 Erection	
			A104040 Timber	A10404010 Fabrication	
				A10404020 Erection	
	A20 Towers	A2010 Foundations	A201010 Spread Footings		A201010X1 Cofferdam
				A20101010 Excavation	
					A201010X2 Formwork
				A20101020 Reinforcement	
				A20101030 Placement	
				A20101040 Backfilling	

Level 1 Major Group Elements	Level 2 Group Elements	Level 3 Individual Elements	Level 4 Sub-Elements	Level 5 Sub-Elements	Level 5 Field Requirements
			A201020 Pile Foundations	A20102010 Test Piles	
				A20102020 Piles	
				A20102030 Pile Cap	
			A201030 Drilled Shafts		A201030X1 Temporary Casing
				A20103010 Permanent Casing	
				A20103020 Rock Socket	
				A20103030 Bell	
				A20103040 Reinforcement	
				A20103050 Placement	
				A20103060 Cap	
		A2020 Walls	A202010 Cast-in-Place Concrete		A202010X1 Formwork
				A20201010 Reinforcement	
				A20201020 Placement	
				A20201030 Finishing	
				A20201040 Coating	
			A202020 Precast Concrete	A20202010 Fabrication	
				A20202020 Erection	
		A2030 Columns	A203010 Cast-in-Place Concrete		A203010X1 Formwork
				A20301010 Reinforcement	
				A20301020 Placement	
				A20301030 Finishing	
			A203020 Precast Concrete	A20302010 Fabrication	
				A20302020 Erection	
			A203030 Steel	A20303010 Fabrication	
				A20303020 Erection	
			A203040 Timber	A20304010 Fabrication	

Level 1 Major Group Elements	Level 2 Group Elements	Level 3 Individual Elements	Level 4 Sub-Elements	Level 5 Sub-Elements	Level 5 Field Requirements
				A20304020 Erection	
		A2040 Cap Beams	A204010 Cast-in-Place Concrete		A204010X1 Formwork
				A20401010 Reinforcement	
				A20401020 Placement	
				A20401030 Finishing	
			A204020 Precast Concrete	A20402010 Fabrication	
				A20402020 Erection	
			A204030 Steel	A20403010 Fabrication	
				A20403020 Erection	
			A204040 Timber	A20404010 Fabrication	
				A20404020 Erection	
	A30 Abutments	A3010 Foundations	A301010 Spread Footings	A30101010 Excavation	
					A301010X1 Formwork
				A30101020 Reinforcement	
				A30101030 Placement	
				A30101040 Backfilling	
			A301020 Piles	A30102010 Test Piles	
				A30102020 Piles	
				A30102030 Pile Cap	
			A301030 Drilled Shafts		A301030X1 Temporary Casing
				A30103010 Permanent Casing	
				A30103020 Rock Socket	
				A30103030 Bell	
				A30103040 Reinforcement	
				A30103050 Placement	
				A30103060 Cap	

Level 1 Major Group Elements	Level 2 Group Elements	Level 3 Individual Elements	Level 4 Sub-Elements	Level 5 Sub-Elements	Level 5 Field Requirements
		A3020 Stems	A302010 Cast-in-Place Concrete		A302010X1 Formwork
				A30201010 Reinforcement	
				A30201020 Placement	
				A30201030 Finishing	
			A302020 Precast Concrete	A30202010 Fabrication	
				A30202020 Erection	
		A3030 Wing Walls	A303010 Cast-in-Place Concrete		A303010X1 Formwork
				A30301010 Reinforcement	
				A30301020 Placement	
				A30301030 Finishing	
			A303020 Precast Concrete	A30302010 Fabrication	
				A30302020 Erection	
	A40 Other Supports	A4010 Thrust Blocks	A401010 Cap		A401010X1 Formwork
				A40101010 Reinforcement	
				A40101020 Placement	
				A40101030 Finishing	
			A401020 Foundations	A40102010 Spread Footings	
				A40102020 Piles	
				A40102030 Drilled Shafts	
		A4020 Anchorage	A402010 Prestressed	A40201010 Spray Saddle	
				A40201020 Anchor	
			A402020 Cast-in-Place Concrete		A402020X1 Formwork
				A40202010 Reinforcement	
				A40202020 Placement	
			A402030 Foundations	A40203010 Spread Footings	
				A40203020 Piles	

Level 1 Major Group Elements	Level 2 Group Elements	Level 3 Individual Elements	Level 4 Sub-Elements	Level 5 Sub-Elements	Level 5 Field Requirements
				A40203030 Drilled Shafts	
B Superstructure	B10 Short Span Assemblies	B1010 Flexural Members	B101010 Cast-in-Place Concrete		B101010X1 Formwork
				B10101010 Reinforcement	
				B10101020 Placement	
				B10101030 Finishing	
			B101020 Precast Concrete	B10102010 Fabrication	
				B10102020 Erection	
			B101030 Steel	B10103010 Fabrication	
				B10103020 Erection	
			B101040 Timber	B10104010 Fabrication	
				B10104020 Erection	
		B1020 Diaphragms	B102010 Cast-In-Place Concrete		B102010X1 Formwork
				B10201010 Reinforcement	
				B10201020 Placement	
			B102020 Precast Concrete	B10202010 Fabrication	
				B10202020 Erection	
			B102030 Steel	B10203010 Fabrication	
				B10203020 Erection	
			B102040 Timber		
		B1030 Bracings	B103010 Steel	B10301010 Fabrication	
				B10301020 Erection	
			B103020 Timber		
		B1040 Bearings	B104010 Elastomeric		
			B104020 Sliding		
			B104030 Roller		

Level 1 Major Group Elements	Level 2 Group Elements	Level 3 Individual Elements	Level 4 Sub-Elements	Level 5 Sub-Elements	Level 5 Field Requirements
	B20 Long Span Assemblies	B2010 Ribs	B201010 Cast-in-Place Concrete		B201010X1 Formwork
				B20101010 Reinforcement	
				B20101020 Placement	
			B201020 Precast Concrete	B20102010 Fabrication	
				B20102020 Erection	
			B201030 Steel	B20103010 Fabrication	
				B20103020 Erection	
		B2020 Cables	B202010 Wires		
			B202020 Sockets		
			B202030 Saddles		
			B202040 Housings		
			B202050 Strands		
			B202060 Anchor Sockets		
		B2030 Hangers	B203010 Top Anchor Socket		
			B203020 Strand		
			B203030 Boot		
			B203040 Spacer		
			B203050 Bottom Anchor Socket		
		B2040 Spandrels	B204010 Cast-in-Place Concrete		B204010X1 Formwork
				B20401010 Reinforcement	
				B20401020 Placement	
				B20401030 Finishing	
			B204020 Precast Concrete	B20402010 Fabrication	
				B20402020 Erection	

Level 1 Major Group Elements	Level 2 Group Elements	Level 3 Individual Elements	Level 4 Sub-Elements	Level 5 Sub-Elements	Level 5 Field Requirements
			B204030 Steel	B20403010 Fabrication	
				B20403020 Erection	
		B2050 Ties	B205010 Cast-in-Place Concrete		B205010X1 Formwork
				B20501010 Reinforcement	
				B20501020 Placement	
			B205020 Precast Concrete	B20502010 Fabrication	
				B20502020 Erection	
			B205030 Steel	B20503010 Fabrication	
				B20503020 Erection	
			B205040 Splices		
			B205050 Connections		
		B2060 Truss members	B206010 Members		
			B206020 Splices		
			B206030 Connections		
		B2070 Segmental Box Girders	B207010 Main Members		
			B207020 Placement	B20702010 Erection	
					B207010X1 Temporary Support
					B207010X2 Temporary Post Tensioning
				B20702020 Permanent Post Tensioning	
				B20702030 Closure Piece Placement	

Level 1 Major Group Elements	Level 2 Group Elements	Level 3 Individual Elements	Level 4 Sub-Elements	Level 5 Sub-Elements	Level 5 Field Requirements
	B30 Deck	B3010 Structural Surface	B301010 Cast-in-Place Concrete		B301010X1 Formwork
				B30101010 Reinforcement	
				B30101020 Placement	
				B30101030 Finishing	
			B301020 Precast Concrete	B30102010 Fabrication	
				B30102020 Erection	
			B301030 Steel	B30103010 Metal Deck	
				B30103020 Connections	
			B301040 Timber	B30104010 Plank	
				B30104020 Connections	
		B3020 Wearing Surface	B302010 Cast-in-Place Concrete	B30201010 Placement	
				B30201020 Finishing	
			B302020 Asphalt	B30202010 Placement	
				B30202020 Finishing	
			B302030 Rails		
C Protection	C10 Structure Protection	C1010 Slope Walls	C101010 Cast-in-Place Concrete	C10101010 Reinforcement	
				C10101020 Placement	
				C10101030 Finishing	
			C101020 Asphalt	C10102010 Gravel	
				C10102020 Placement	
			C101030 Stone		
		C1020 Expansion Joint	C102010 Strip-Seal		
			C102020 Modular		
			C102030 Finger Plate		
		C1030 Protective Coats	C103010 Preparation		
			C103020 Application		

Level 1 Major Group Elements	Level 2 Group Elements	Level 3 Individual Elements	Level 4 Sub-Elements	Level 5 Sub-Elements	Level 5 Field Requirements
		C1040 Sacrificial Beams	C104010 Fabrication		
			C104020 Erection		
		C1050 Drainage System	C105010 Scuppers		
			C105020 Drain Pipes		
			C105030 Buried Drains	C10503010 Pipe	
				C10503020 Head Wall	
				C10503030 End Walls	
		C1060 Inspection and Maintenance Systems	C106010 Hangers		
			C106020 Beams		
			C106030 Platform		
			C106040 Railing		
			C106050 Connections		
	C20 Traffic Protection	C2010 Barriers	C201010 Parapet		
			C201020 Railing		
			C201030 Glare Screen		
			C201040 Median		
			C201050 Curb		
			C201060 Guardrail		
			C201070 Screen		
		C2020 Protective Shields	C202010 Fabrication		
			C202020 Erection		
		C2030 Traffic Controls	C203010 Signals		
			C203020 Arms		
			C203030 Mast		
			C203040 Base Plate		
			C203050 Conduits		

Level 1 Major Group Elements	Level 2 Group Elements	Level 3 Individual Elements	Level 4 Sub-Elements	Level 5 Sub-Elements	Level 5 Field Requirements
	C30 Other Protection	C3010 Lighting	C301010 Lights		
			C301020 Arms		
			C301030 Mast		
			C301040 Base Plate		
			C301050 Conduits		
		C3020 Signage	C302010 Sign Board		
			C302020 Support		
			C302030 Lights		
			C302040 Conduits		
		C3030 Sound Barrier Walls	C303010 Panels		
			C303020 Support		
			C303030 Connections		
		C3040 Air Pressure Barriers	C304010 Panels		
			C304020 Support		
			C304030 Connections		
		C3050 Enclosure	C305010 Vertical Envelope		
			C305020 Roof		
D Sitework	D10 Site Preparation	D1010 Clearing and Grubbing	D101010 Clearing		
			D101020 Grubbing		
		D1020 Demolition and Relocation	D102010 Structures		
			D102020 Utilities		
			D102030 Trees		
		D1030 Earthwork	D103010 Cut		
			D103020 Fill		
		D1040 Hazardous Material Handling	D104010 Excavation		
			D104020 Disposal		

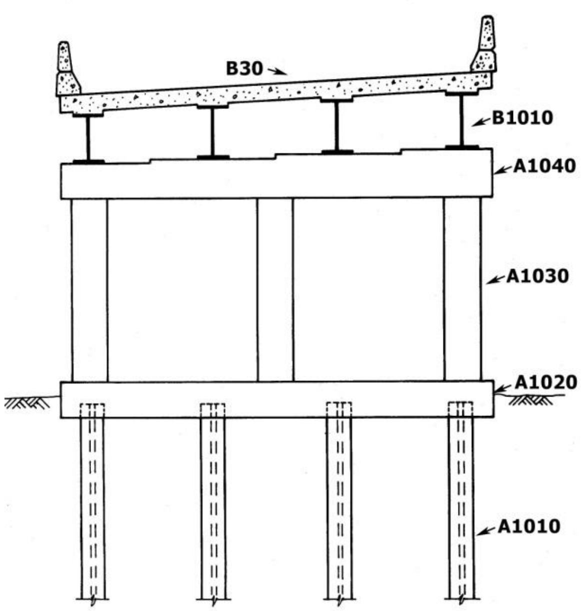
Level 1 Major Group Elements	Level 2 Group Elements	Level 3 Individual Elements	Level 4 Sub-Elements	Level 5 Sub-Elements	Level 5 Field Requirements
		D1050 Environmental Restoration/ Replacement	D105010 Environmental Restoration		
			D105020 Environmental Replacement		
	D20 Approach Construction	D2010 Approach Slab	D201010 Reinforcement		
			D201020 Placement		
			D201030 Finishing		
		D2020 Sleeper Slab	D202010 Excavation		
			D202020 Reinforcement		
			D202030 Placement		
			D202040 Backfilling		
		D2030 Earth Retention System	D203010 Foundation		
			D203020 Wall		
			D203030 Cap		

Appendix B An Illustrated Guide to the Proposed UNIFORMAT II Classification of Bridge Elements

This appendix is designed as an illustrated guide to the proposed UNIFORMAT II classification of bridge elements. The appendix includes diagrams, engineering drawings, and, where appropriate, photographs to identify the appearance of each element and how it fits into the overall framework.

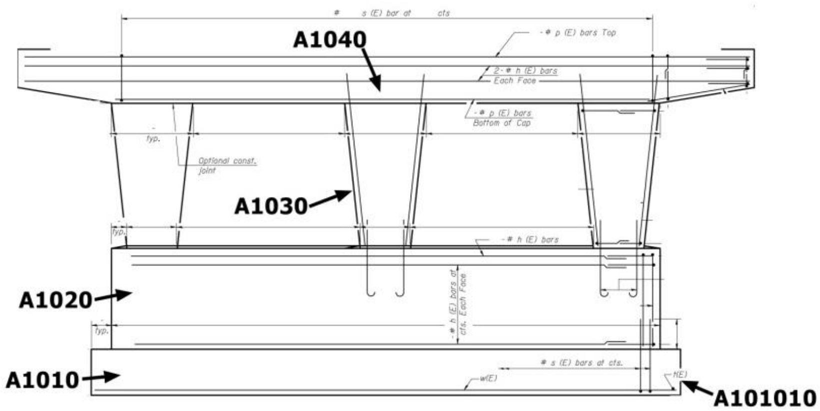
The figures presented in this appendix are organized around the proposed UNIFORMAT II hierarchy. Figures are arranged by Major Group Element and Group Element, with Individual Elements clearly marked in the diagram, engineering drawing, or photograph. For each Major Group Element, the Group Elements are presented in the sequence they are listed in Table 2.2. For each Group Element, the Individual Elements are labeled in one of more figures associated with that Group element. In some case, Sub-Elements are also listed.

Figure B.1 Major Group Elements: A Substructure, B Superstructure



Source: Illinois Department of Transportation

Figure B.2 Group Elements: A10 Piers

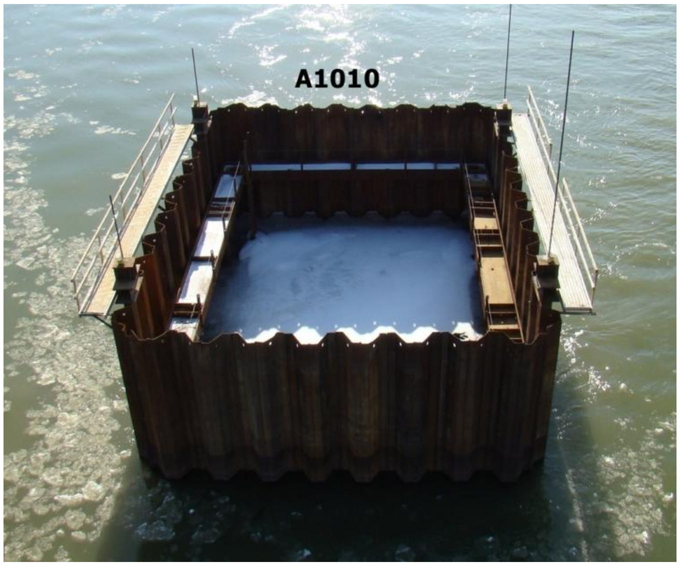


Source: Illinois Department of Transportation

Figure B.3 Group Elements: A10 Piers

Source: Alfred Benesch & Company

Figure B.4 Individual Elements: A1010 Foundations (Field Requirements: A101010X1 (Cofferdam))

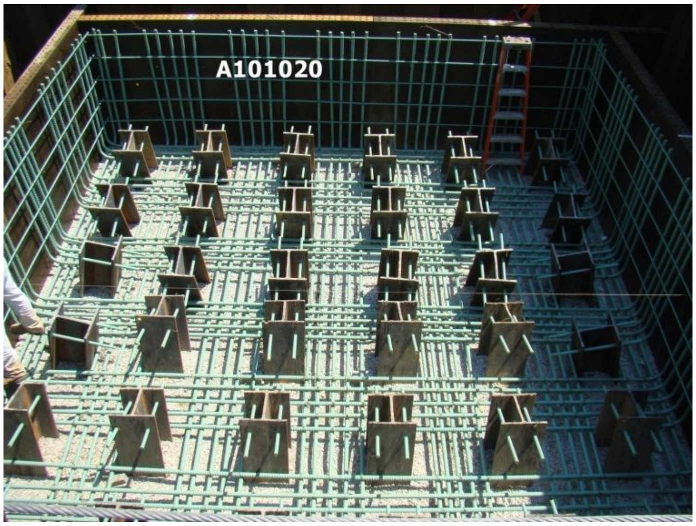


Source: Alfred Benesch & Company

Figure B.5 Individual Elements: A1010 Foundations (Sub-Elements: A101010 Spread Footings (Excavation))

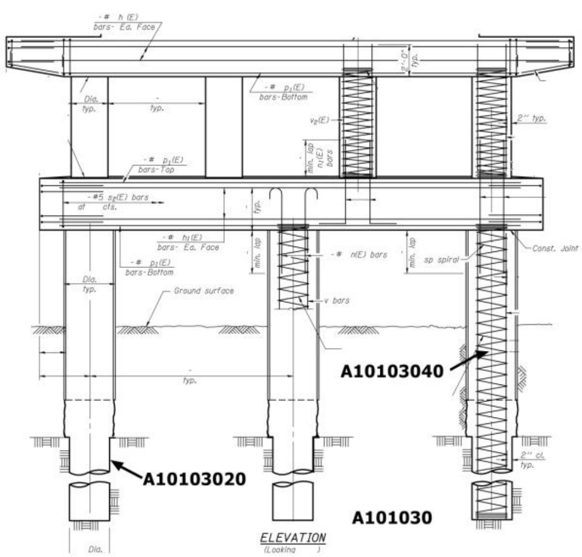
Source: Alfred Benesch & Company

Figure B.6 Individual Elements: A1010 Foundations (Sub-Elements: A101020 Piles)



Source: Alfred Benesch & Company

Figure B.7 Individual Elements: A1010 Foundations (Sub-Elements: A101030 Drilled Shafts)



Source: Illinois Department of Transportation

Figure B.8 Individual Elements: A1020 Walls, A1030 Columns, A1040 Cap Beams

Source: Alfred Benesch & Company

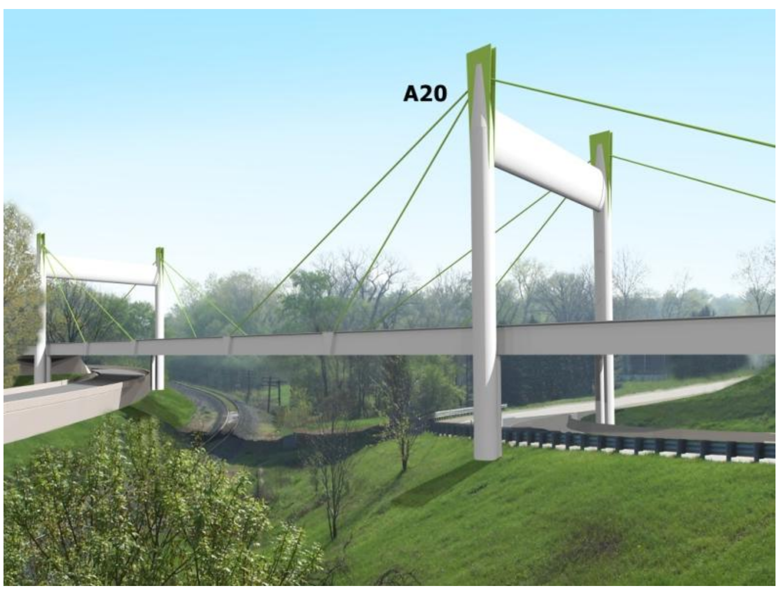
Figure B.9 Individual Elements: A1040 Cap Beams (Sub-Elements: A10401020 Reinforcement)

Source: Alfred Benesch & Company

Figure B.10 Individual Elements: A1040 Cap Beams

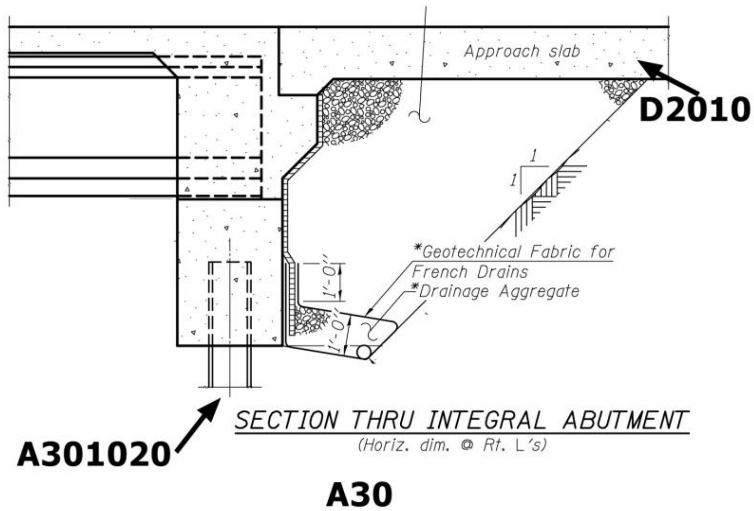
Source: Alfred Benesch & Company

Figure B.11 Group Elements: A20 Towers



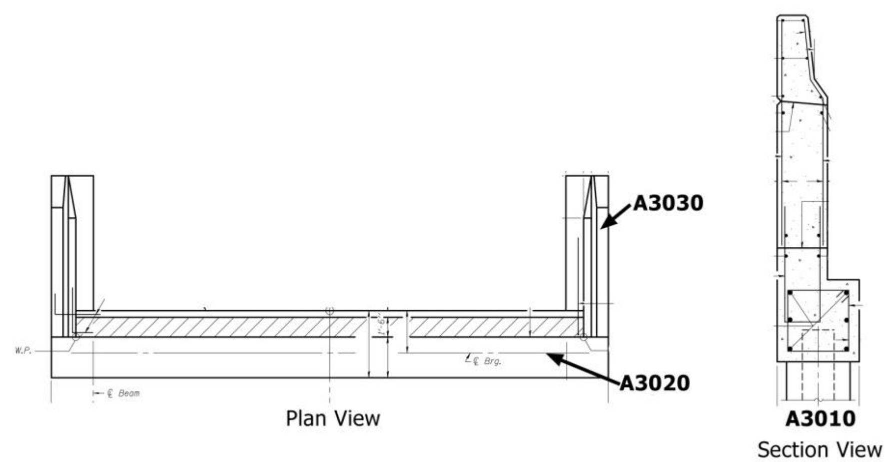
Source: Alfred Benesch & Company

Figure B.12 Group Elements: A30 Abutments



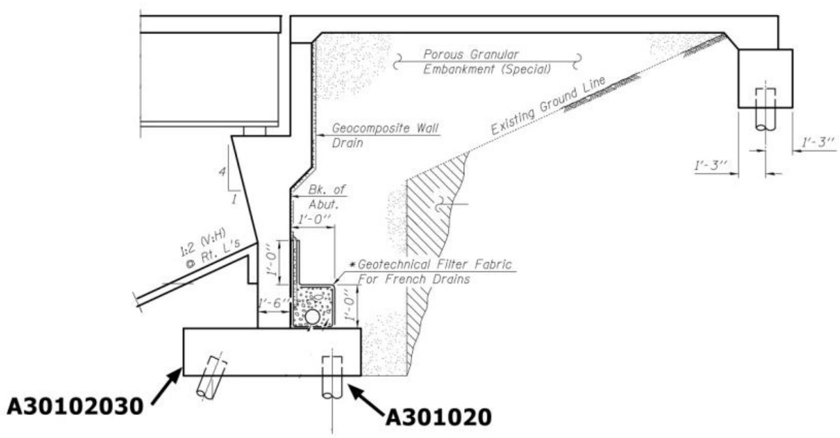
Source: Illinois Department of Transportation

Figure B.13 Individual Elements: A3010 Foundations, A3020 Stems, A3030 Wing Walls



Source: Illinois Department of Transportation

Figure B.14 Individual Elements: A3010 Foundations (Sub-Elements: A301020 Piles, A30102030 Pile Cap)



Source: Illinois Department of Transportation

Figure B.15 Individual Elements: A3020 Stems

Source: Alfred Benesch & Company

Figure B.16 Individual Elements: A3030 Wing Walls

Source: Alfred Benesch & Company

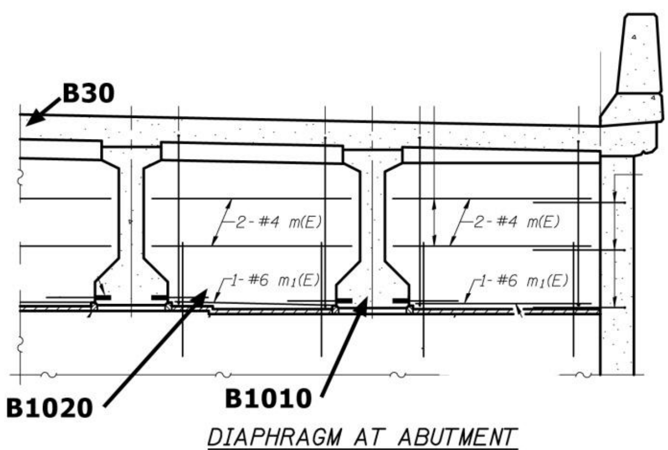
Figure B.17 Group Elements: A40 Other Supports (Individual Elements: A4010 Thrust Blocks)

Source: Alfred Benesch & Company

Figure B.18 Individual Elements: A4010 Thrust Blocks (Sub-Elements: A401020 Foundations (A40102020 Piles))

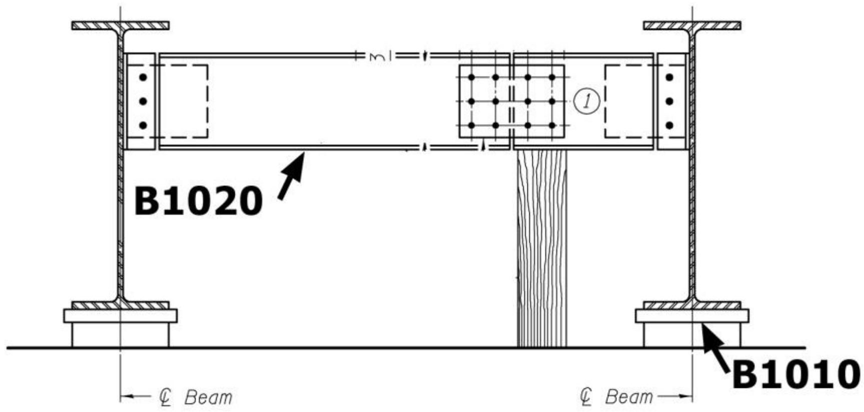
Source: Alfred Benesch & Company

Figure B.19 Group Elements: B10 Short Span Assemblies (Individual Elements: B1010 Flexural Member, B1020 Diaphragms), B30 Deck



Source: Illinois Department of Transportation

Figure B.20 Individual Elements: B1010 Flexural Members, B1020 Diaphragms

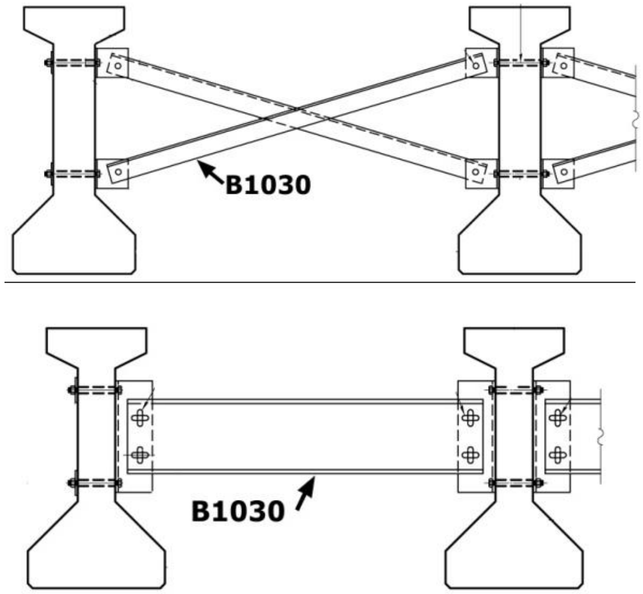


Source: Illinois Department of Transportation

Figure B.21 Individual Elements: B1020 Diaphragms

Source: Alfred Benesch & Company

Figure B.22 Individual Elements: B1030 Bracings



Source: Illinois Department of Transportation

Figure B.23 Individual Elements: B1030 Bracings

Source: Alfred Benesch & Company

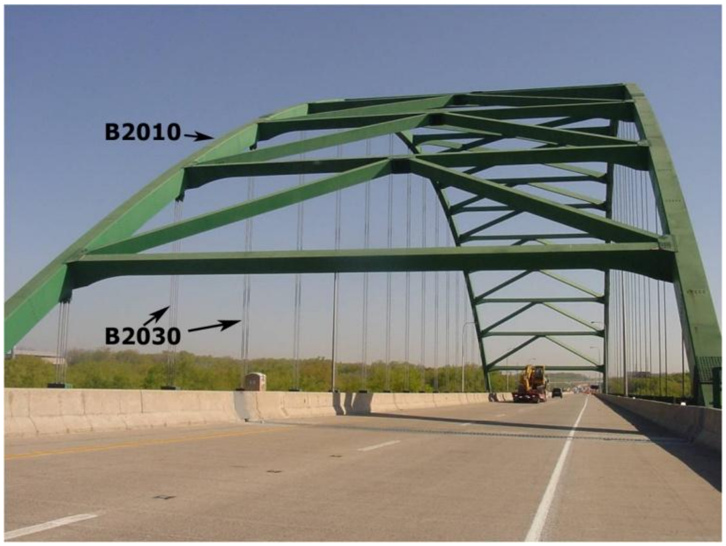
Figure B.24 Individual Elements: B1040 Bearings

Source: Alfred Benesch & Company

Figure B.25 Individual Elements: B1010 Flexural Members, B1030 Bracings, B1040 Bearings

Source: Alfred Benesch & Company

Figure B.26 Group Elements: B20 Long Span Assemblies (Individual Elements: B2010 Ribs, B2030 Hangers)



Source: Alfred Benesch & Company

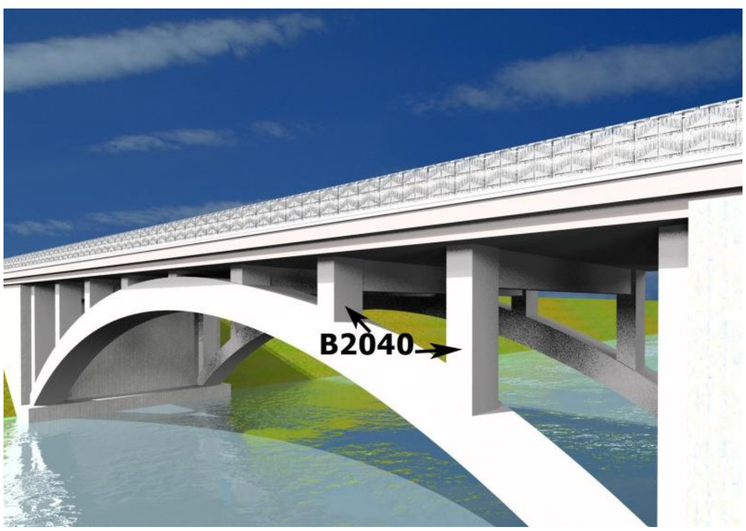
Figure B.27 Individual Elements: B2030 Hangers

Source: Alfred Benesch & Company

Figure B.28 Individual Elements: B2010 Ribs, B2050 Ties

Source: Alfred Benesch & Company

Figure B.29 Individual Elements: B2040 Spandrels



Source: Alfred Benesch & Company

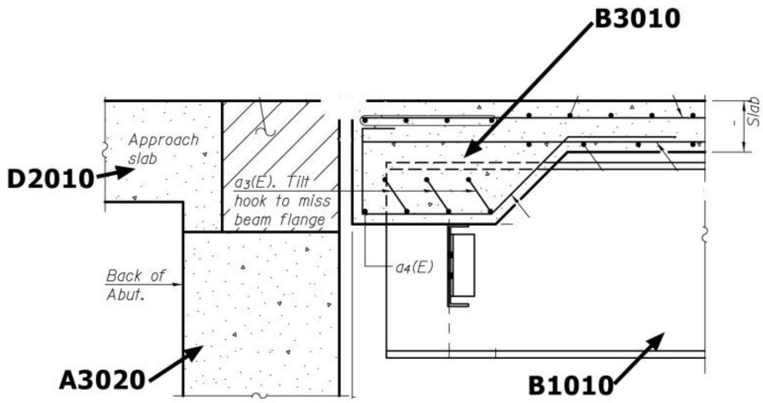
Figure B.30 Individual Elements: B2060 Truss Members

Source: Alfred Benesch & Company

Figure B.31 Individual Elements: B2070 Segmental Box Girders

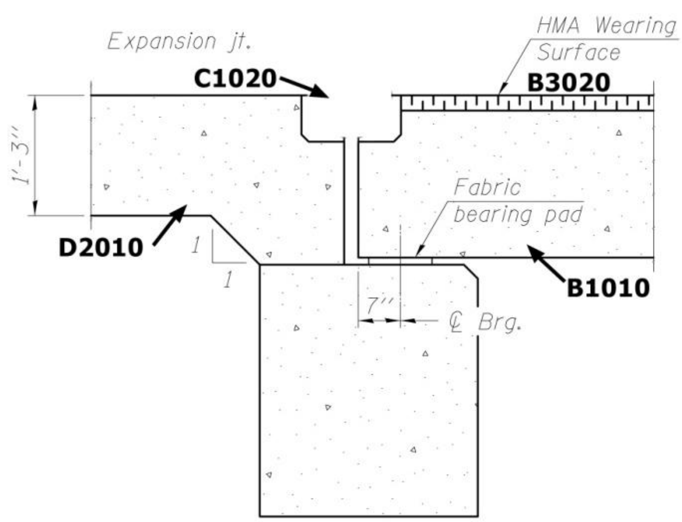
Source: Alfred Benesch & Company

Figure B.32 Group Elements: B30 Deck (Individual Elements: B3010 Structural Surface)



Source: Illinois Department of Transportation

Figure B.33 Individual Elements: B3020 Wearing Surface



Source: Illinois Department of Transportation

Figure B.34 Group Elements: C10 Structure Protection (Individual Elements:C1010 Slope Walls)

Source: Alfred Benesch & Company

Figure B.35 Individual Elements: C1020 Expansion Joints

Source: Alfred Benesch & Company

Figure B.36 Individual Elements: C1030 Protection Coats

Source: Alfred Benesch & Company

Figure B.37 Individual Elements: C1040 Sacrificial Beams

Source: Alfred Benesch & Company

Figure B.38 Individual Elements: C1050 Drainage Systems

Source: Alfred Benesch & Company

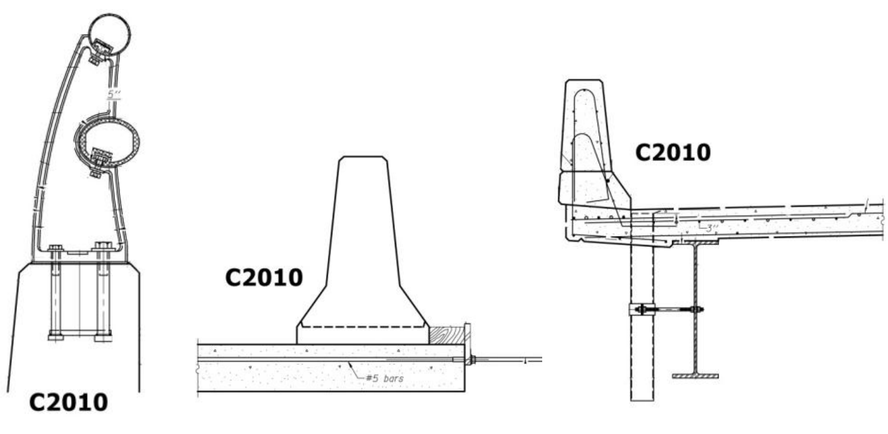
Figure B.39 Individual Elements: C1050 Drainage Systems (Sub-Elements C105030 Buried Drains (C10503020 Head Walls, C10503030 End Walls))

Source: Alfred Benesch & Company

Figure B.40 Individual Elements: C1060 Inspection and Maintenance Systems

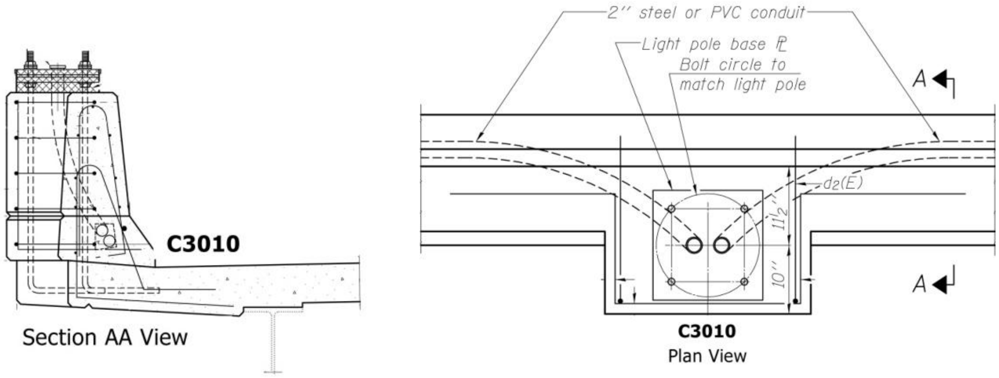
Source: Alfred Benesch & Company

Figure B.41 Individual Elements: C2010 Barriers



Source: Illinois Department of Transportation

Figure B.42 Group Elements: C30 Other Protection (Individual Elements: C3010 Lighting)



Source: Illinois Department of Transportation

Figure B.43 Individual Elements: C3010 Lighting, C3020 Signage

Source: Alfred Benesch & Company

Figure B.44 Individual Elements: C3020 Signage

Source: Alfred Benesch & Company

Figure B.45 Individual Elements: C3030 Sound Barrier Walls

Source: Alfred Benesch & Company

Figure B.46 Individual Elements: C3050 Enclosure

Source: Alfred Benesch & Company

Figure B.47 Major Elements: D Sitework (Group Elements: D10 Site Preparation (Individual Elements: D1010 Clearing and Grubbing))

Source: Alfred Benesch & Company

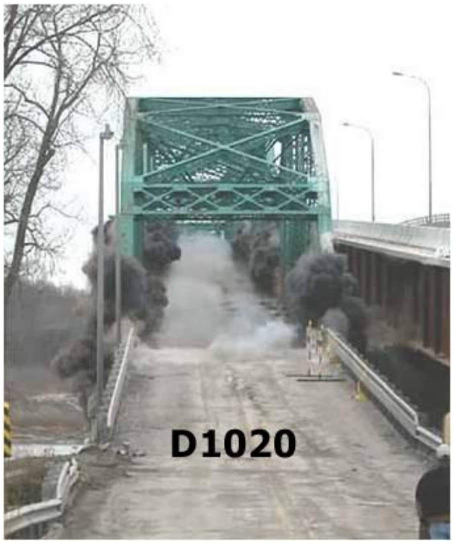
Figure B.48 Individual Elements: D1010 Clearing and Grubbing (Sub-Element D101010 Clearing (Tree Removal))

Source: Alfred Benesch & Company

Figure B.49 Group Elements: D10 Site Preparation (Individual Elements: D1020 Demolition and Relocation)

Source: Alfred Benesch & Company

Figure B.50 Individual Elements: D1020 Demolition and Relocation

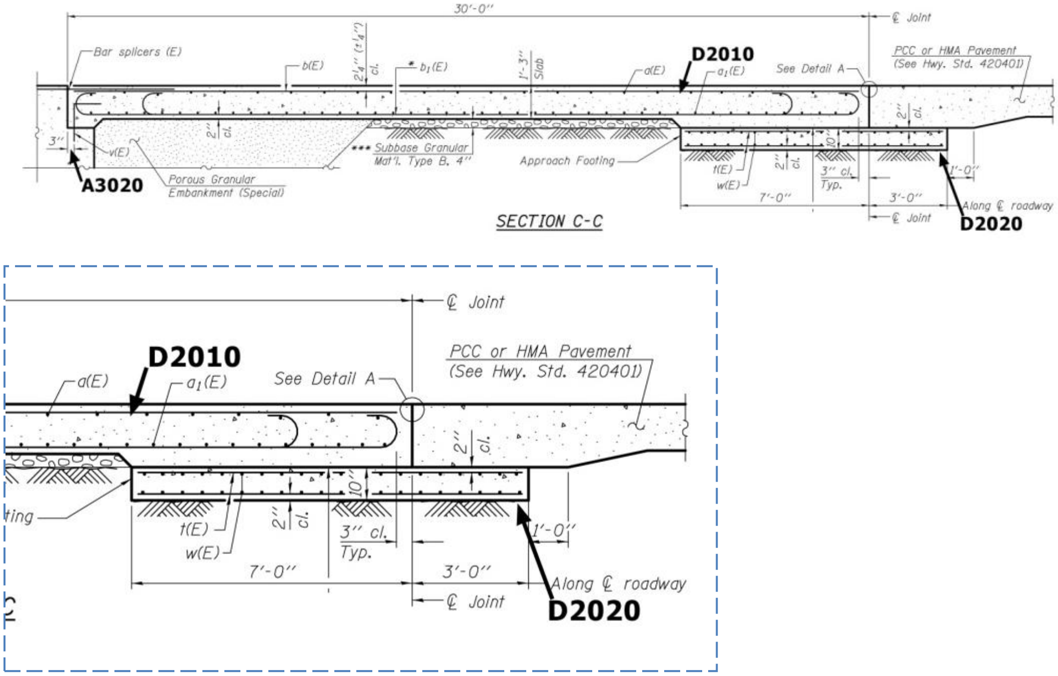


Source: Alfred Benesch & Company

Figure B.51 Individual Elements: D1030 Earthwork

Source: Alfred Benesch & Company

Figure B.52 Group Elements: D20 Approach Construction (Individual Elements: D2010 Approach Slabs, D2020 Sleeper Slabs)



Source: Illinois Department of Transportation

Figure B.53 Individual Elements: D2030 Earth Retention System

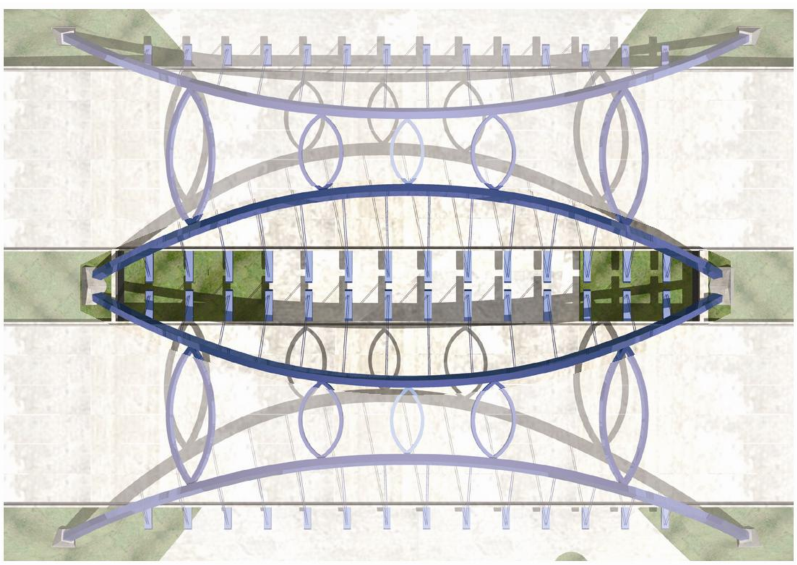
Source: Alfred Benesch & Company

Appendix C Application of Proposed UNIFORMAT II Classification and Sub-Classifications to a Single-Span, Modified Tied-Arch Bridge

C.1 Summary of Key Bridge Characteristics

This appendix uses a case study bridge construction project to demonstrate how to use the proposed UNIFORMAT II classification and sub-classifications to analyze and manage bridge design and construction costs. The bridge is a dual single-span, modified tied-arch carrying six lanes of Interstate 94 (I-94) traffic (three eastbound and three westbound) over Telegraph Road in Taylor, Michigan. Figure C.1 provides an overhead view of the two bridge structures. This bridge was part of the reconstruction of I-94 for the Super Bowl XL game held in 2006. Figures C.2 and C.3 provide different perspectives of the bridge as seen from Telegraph Road (Figure C.2) and from I-94 (Figure C.3).

Figure C.1 Overhead View of the Gateway Arch Bridge



Source: Alfred Benesch & Company

Many modern bridges are either true arches or tied arches. The modified tied-arch bridge in Taylor, Michigan, combined the two concepts for aesthetic and safety reasons. Tied arches, where the tie is exposed, might be hit by trucks and are not desirable for grade separation structures. True arches, where the thrust must be taken by the foundation elements, are exposed to risk when the soil conditions are poor. The Gateway Arch, as it is now called, is a signature structure modified to look like a true arch with a tied foundation. The thrust blocks are connected below the roadway by a rectangular concrete tie beam. The arch ribs are unequal to keep the two bridges closer together. The stiffness of the ribs is varied to keep the same deflection. To allow for inspections without disturbing the heavy traffic on I-94, the ribs were sealed and pressurized. Pressure gauges were added to detect any leaks.

Figure C.2 Gateway Arch Bridge as Seen from Telegraph Road

Source: Alfred Benesch & Company

Figure C.3 Gateway Arch Bridge as Seen from I-94

Source: Alfred Benesch & Company

The project team was challenged with two major criteria: cost and structural integrity. The team approached the design by analyzing its functions and its worth. The team value engineered the conventional design of elements and identified the function, cost, and performance of each element using ASTM Standard Practice E 2013.[41] If the function need/performance is high and cost is low, it has value. If the function need/performance is low and cost is high, it becomes a mismatch. When mismatches of conventional design are identified, the team develops innovative solutions to create value of the elements that has a higher need/performance at a lower cost.

Unique Foundation System

In true arches, the thrust is taken by the foundation supports, such as piles. In tied arches, the thrust is taken internally by tie beams. There is no redundancy in case of a failure of the thrust resistance. For this modified tied-arch, the longitudinal arch thrust is resisted by multiple foundation elements as shown in Figure C.4: the longitudinal foundation ties, the transverse foundation ties, and battered piles. The concrete foundation ties, buried beneath Telegraph Road (see the photograph on the right-hand side of Figure C.4), are sized so that the tensile strength of the concrete is sufficient to carry the arch thrust. However, should the concrete crack, there is adequate reinforcement in the tie. There are also 10 cm (4 in) diameter open ducts cast in concrete ties. At present, these are capped but the tie can be post-tensioned if deemed necessary. In addition, battered piles and massive earth pressure against the foundation also resist arch thrust.

Figure C.4 Gateway Arch Bridge Foundation System

Source: Alfred Benesch & Company

[41] ASTM International. "Practice for Constructing FAST Diagrams and Performing Function Analysis During Value Analysis Study," E 2013, *op cit.*

Arch Ribs

Each structure is a single-span inclined through arch. The interior and exterior arch ribs are inclined 25 degrees towards each other. The inclination is limited to 25 degrees in order to maintain the desirable vertical clearance. The ribs are braced together using five football shaped braces (see Figures C.5 and C.6). The bases of the exterior arch ribs are located at the Telegraph Road level, while the bases of the interior ribs are located at the I-94 level. This caused the length of the exterior rib and the interior rib to be different. The length of the exterior and interior arch ribs are 90.2 m (296 ft) and 78.3 m (257 ft), respectively. The span length measured between the east and west abutments is 75.0 m (246 ft).

Figure C.5 Longitudinal View of the Arch Ribs

Source: Alfred Benesch & Company

The unequal lengths of the arches posed a challenge to the design team. The arch rib deflection due to dead and live loads will be different. By carefully varying the stiffness of the box while maintaining the outside shape and dimension the same, both the appearance and structural integrity were achieved. The inner thrust block is at the road level of I-94; the outer thrust block is at the level of Telegraph Road.

Figure C.6   Transverse View of the Arch Ribs Illustrates Unequal Lengths

Source: Alfred Benesch & Company

The ribs are fixed at each end by the foundation. The arch ribs are a 0.9 m by 1.2 m (3 ft by 4 ft) box section. The webs of the ribs are 1.91 cm (0.75 in) thick. The flanges for the exterior ribs and interior ribs are 6.35 cm (2.5 in) thick and 5.72 cm (2.25 in) thick, respectively.

Maintenance of Arch Ribs

Due to the small size of the arch ribs, future inspection and maintenance of the inside portion of the box is virtually impossible. Therefore, the arch ribs, arch braces, and the boxed-sections of transverse beams are pressurized with dry air to prevent moist air from entering the boxed-sections to cause corrosion. In order to prevent any air leakage from the pressurized sections, the top flanges of the arch ribs and braces are welded to the webs using a full penetration weld. The bottom flanges are welded to the webs using a double side fillet weld. A trapezoidal shape-sealing diaphragm is located inside the arch box at each hanger location. The portion inside the sealing diaphragm is not pressurized, and an access opening in the web is provided to facilitate inspection of the unsealed portion of the arch.

Figure C.7   Access Opening to the Arch Rib

Source: Alfred Benesch & Company

Access openings in the arch ribs are furnished where the air pressure can be checked (see Figure C.7). At each arch rib field splice location, one pressure valve is attached to the sealing diaphragm. The arch rib segments are sealed and pressurized with air at 55.2 kilopascal (kpa) (8.0 pounds per square inch (psi)). If the pressure inside the sealed chamber drops by more than 10.3 kpa (1.5 psi) from the 55.2 kpa (8 psi) norm, then the reason for the air leak should be investigated.

Redundancy of Hanger Assembly

Each arch has 14 hanger assemblies that transfer the loads from the deck to the arch ribs. The hanger assembly posed a number of challenges. First, the hangers were changed from rods to strands. Because the hangers are a critical element in carrying the load, it was decided to increase the redundancy. Thus, each hanger assembly has a pair of strands, each one capable of carrying the total load (see the photograph on the left-hand side of Figure C.8).

Figure C.8   Hanger Assembly and Neoprene Transition Boots

Source: Alfred Benesch & Company

Each hanger assembly consists of two 5.4 cm (2.125 in) diameter, ASTM A586 structural stands, spaced 38.1 cm (15 in) center to center. The inner wires of each strand are galvanized with Class A coating, while the outer wires are galvanized with Class C coating. Each strand is attached to the arch ribs using a 4.45 cm (1.75 in) thick hanger support plate and ASTM A148 Grade 105/85 galvanized open type socket.

Neoprene transition boots, secured to 25.4 cm (10 in) diameter standard pipe, welded to the transverse beams and to the strands using stainless steel clamps, are used to prevent moisture from entering inside the connections between the transverse beams and the strands and to enhance aesthetics (see the photograph on the right-hand side of Figure C.8). A hanger separator is installed between the two strands of each hanger assembly for the middle ten hangers. Hanger separators increase in-plane stiffness of the strands by constraining the relative motions between them and increasing the stiffness of the hanger against transverse winds.

The bridge was designed to facilitate the replacement of individual strands. Each strand of the pair is capable of supporting the deck and the full live load while the other is replaced.

C.2 Cost Accounting Framework

The costs of each element are organized around the proposed UNIFORMAT II classification of bridge elements, as described in Table 2.3. Because these costs have associated with them project management functions and risk management functions, two additional tables are needed. Table C.1 covers program management-related costs and Table C.2 covers risk management-related costs. Each table is organized as a three-level hierarchy.

Table C.1 Classification Hierarchy for Program Management-Related Costs

Level 1 Major Group Classification	Level 2 Group Classification	Level 3 Individual Classification
X Project Management	X10 Field Requirements	X1005 Bonds, Permits, Fees, and Insurance
		X1010 Field/Site Set-Up and Accommodation
		X1015 Management, Supervision, and Field Engineering
		X1020 Personnel Travel and Lodging
		X1025 Safety and Protection
		X1030 Construction Aids, Equipment, and Tools
		X1035 Temporary Construction
		X1040 Climatic and Environmental Requirements
		X1045 Quality Control, Inspection, and Testing
		X1050 Maintenance and Housekeeping
		X1090 Other Contractural Requirements
	X20 Office Overhead and Profit	X2010 Home Office Overhead
		X2020 Profit

Table C.2 Classification Hierarchy for Risk Management-Related Costs

Level 1 Major Group Classification	Level 2 Group Classification	Level 3 Individual Classification
Y Risk Management	Y10 Allowance	Y1010 Specific
		Y1020 Nonspecific
	Y20 Contingency	Y2010 Specific
		Y2020 Nonspecific
	Y30 Reserve Sums	Y3010 Specific
		Y3020 Nonspecific

The prefix in Table C.1 is X indicating its relationship to Table 1 in ASTM E 2083, Standard Classification for Building Construction Field Requirements and Office Overhead and Profit. Level 1 in the hierarchy contains the single entry X Project Management. Level 2 in the hierarchy contains two entries: X10 Field Requirements and X20 Office Overhead and Profit. Level 3 entries under X10 Field Requirements include such cost items as X1030 Construction Aids, Equipment, and Tools (e.g., cranes and scaffolding) and X1035 Temporary Construction (e.g., coffer dams).

The Prefix in Table C.2 is Y indicating its relationship to ASTM E 2168, Standard Classification for Allowance, Contingency, and Reserve Sums in Building Construction Estimating. Due to the unique characteristics of the Gateway Arch Bridge, ASTM E 2168 was of particular importance. Level 1 in the hierarchy contains the single entry Y Risk Management. Level 2 in the hierarchy contains three entries: Y10 Allowance, Y20 Contingency, and Y30 Reserve Sums. The two Level 3 entries under Y10 Allowance are: Y1010 Specific and Y1020 Nonspecific. There are similar breakdowns for Y20 Contingency and Y30 Reserve Sums. For example, under Y20 Contingency, Y2010 Specific covers planning contingency, design contingency, and construction contingency, whereas Y2020 Nonspecific covers overall unexpected events or items. As the project progresses, some of the planning and design contingencies will be moved into the base cost. Construction contingency will remain until the construction is complete.

In addition to the three risk management terms—allowance, contingency, and reserve sums—included in ASTM E 2168, it is useful to introduce a fourth term, base cost. Base cost includes all costs for the construction work including all trade costs and the prime contractor's field requirements and office overhead and profit reported in Table C.1. It is instructive to review the relationship between these four cost terms. Understanding these relationships is at the heart of analyzing and managing design and construction costs for complex projects such as the Gateway Arch Bridge. Base cost plus allowance is designated as the ***minimum cost***. Base cost plus allowance and contingency is designated as the ***expected cost***. Base cost plus allowance, contingency, and reserve sums is designated as the ***maximum cost***.

C.3 Cost Analysis of the Gateway Arch Bridge Using the Proposed UNIFORMAT II Elemental Classification and Sub-Classifications

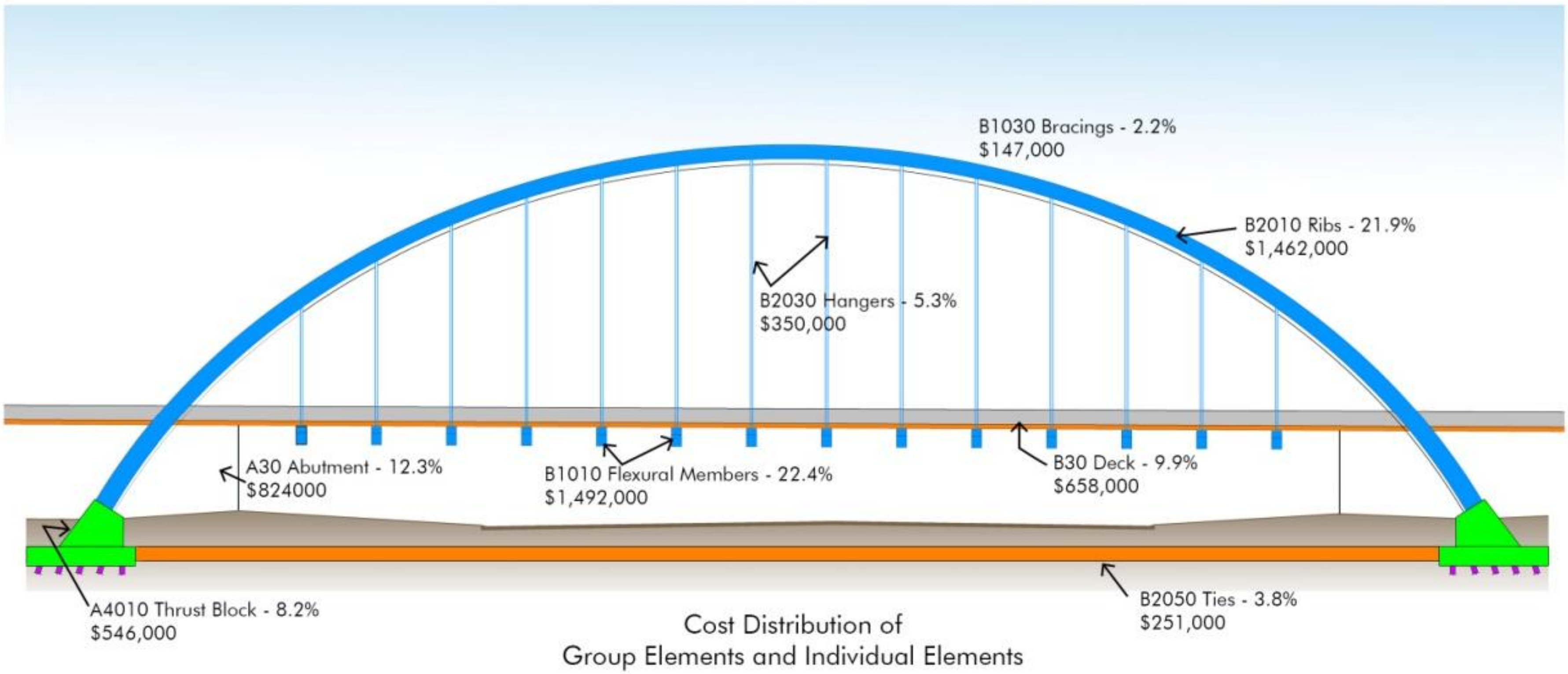
The total cost for one of the two bridge structures making up the Gateway Arch Bridge is \$6.76 million. Since the two bridge structures are identical, their total costs are the same. The cost analysis of the Gateway Arch Bridge using the proposed UNIFORMAT II elemental classification and sub-classifications is presented in Table C.3 and summarized in Figure C.9. Table C.3 records information for each of the five levels in the proposed UNIFORMAT II bridge classification. Table C.3 includes alphanumeric designations and element/sub-element names, dollar values, percent of total cost associated with those dollar values, and unit costs. Figure C.9 records the cost distribution of selected Group Elements and Individual Elements. The costs summarized in Figure C.9 are the major Substructure and Superstructure Group Elements and Individual Elements; they account for approximately 85 % of the Gateway Arch Bridge's total cost.

Table C.3 Cost Analysis of the Gateway Arch Bridge Using the Proposed UNIFORMAT II Elemental Classification and Sub-Classifications

Level 1		Level 2		Level 3			Level 4			Level 5	Details			
Major Group Elements		Group Elements		Individual Elements	% Total Cost	Cost	Sub Elements	% Total Cost	Cost	Field Requirements	Quantity	Unit	Unit Cost	Amount
A Substruture		A30 Abutments		A3010 Foundation	4.03%	$268,875	A301020 Piles	4.03%	$268,875	A30102010 Test Piles	1	Each	$16,575.00	$16,575
$1,369,210	**20.5%**	$823,485	12.3%							A30102020 Piles	7060	ft	$30.00	$211,800
Cost/ Sq.Ft	$74.51	Cost/ Sq.Ft	$44.82							A10102030 Pile Cap	90	yd^3	$450.00	$40,500
				A3020 Stems	8.12%	$541,650	A302010 Cast -in-Place Concrete	8.12%	$541,650	A30201010 Reinforcement	94200	lb	$0.75	$70,650
										A30201020 Placement (includes A302010X1 Formwork)	785	yd^3	$600.00	$471,000
				A3030 Wing walls	0.19%	$12,960	A303010 Cast -in- Place Concrete	0.19%	$12,960	A30301010 Reinforcement	3200	lb	$0.80	$2,560
										A30301010 Placement	16	yd^3	$650.00	$10,400
		A40 Other Supports		A4010 Thrust Blocks	8.18%	$545,725	A401010 Cap	5.00%	$333,925	A40101010 Reinforcement	63175	lb	$1.00	$63,175
		$545,725	8.2%							A40101020 Placement (includes A401010X1 Formwork)	361	yd^3	$750.00	$270,750
		Cost/ Sq.Ft	$29.70				A401020 Foundations	3.17%	$211,800	A40102020 Piles	7060	ft	$30.00	$211,800
B Superstructure		B10 Short span assemblies		B1010 Flexural Members	22.36%	$1,492,311	B101030 Steel	22.36%	$1,492,311	B10103010 Fabrication	852749	lb	$1.00	$852,749
$4,493,274	**67.3%**	$1,772,355	26.6%							B10103020 Erection	852749	lb	$0.75	$639,562
Cost/ Sq.Ft	$244.53	Cost/ Sq.Ft	$96.45											
				B1020 Diaphragms	1.10%	$73,500	B102020 Steel	1.10%	$73,500	B10202010 Fabrication	42000	lb	$1.00	$42,000
										B10202020 Erection	42000	lb	$0.75	$31,500
				B1030 Bracings	2.20%	$146,544	B103010 Steel	2.20%	$146,544	B10301010 Fabrication	66611	lb	$1.20	$79,933
										B10301020 Erection	66611	lb	$1.00	$66,611
				B1040 Bearings	0.90%	$60,000	B104020 Sliding	0.90%	$60,000		12	Each	$5,000.00	$60,000
		B20 Long Span Assemblies		B2010 Ribs	21.91%	$1,462,206	B201030 Steel	21.91%	$1,462,206	B20103010 Fabrication	664639	lb	$1.20	$797,567
		$2,063,325	30.9%							B20103020 Erection	664639	lb	$1.00	$664,639
		Cost/ Sq.Ft	$112.29	B2030 Hangers	5.25%	$350,450		5.25%	$350,450		1630	Lin ft	$215.00	$350,450
				B2050 Ties	3.76%	$250,669	B205010 Cast- in- Place Concrete	3.76%	$250,669	B20501010 Reinforcement	74461.5	lb	$0.80	$59,569
										B20501020 Placement	294	yd^3	$650.00	$191,100
		B30 Deck		B3010 Structural Surface	7.13%	$476,094	B301010 Cast- in- Place Concrete	7.13%	$476,094	B30101010 Reinforcement	209180	lb	$0.80	$167,344
		$657,594	9.9%							B30101020 Placement	475	yd^3	$650.00	$308,750
		Cost/ Sq.Ft	$35.79	B3020 Wearing Surface	2.72%	$181,500					2420	yd^2	$75.00	$181,500
C Protection		C10 Structure Protection												
$186,440	**2.8%**	$4,000	0.1%	C1020 Expansion Joint	0.06%	$4,000					80	Lin ft	$50.00	$4,000
Cost/ Sq.Ft	$10.15	Cost/ Sq.Ft	$0.22											
		C20 Traffic protection		C2010 Barriers	0.49%	$33,000					66	yd^3	$500.00	$33,000
		$57,440	0.9%	C2020 Protective Shields	0.37%	$24,440					24440	yd^2	$1.00	$24,440
		Cost/ Sq.Ft	$3.13											
		C30 Other Protection												
		$125,000	1.9%	C3010 Lighting	1.87%	$125,000					1	Each	$125,000.00	$125,000
		Cost/ Sq.Ft	$6.80											
D Sitework		D10 Site Preparation		D1010 Clearing and Grubbing	0.97%	$65,000					1	Each	$65,000.00	$65,000
$624,998	**9.4%**	$572,938	8.6%	D1020 Demolition and Relocation	7.25%	$483,615					1	Each	$483,615.00	$483,615
Cost/ Sq.Ft	$34.01	Cost/ Sq.Ft	$31.18	D1030 Earthwork	0.36%	$24,323	D103010 Cut	0.36%	$24,323		2115	yd^3	$11.50	$24,323
		D20 Approach Construction		D2010 Approach Slabs	0.72%	$48,060					267	yd^2	$180.00	$48,060
		$52,060	0.8%	D2020 Sleeper Slabs	0.06%	$4,000					80	ft	$50.00	$4,000
		Cost/ Sq.Ft	$2.83											

Bridge Geometry	**Total Bridge Cost**		**$6,673,921**		
Length of Bridge (Back to Back of Abutments)		245	Ft		
Width of Bridge (Back to Back of Barriers)		75	Ft		
Deck Area of Bridge		18375	Sq.Ft	**Cost/ Sq.Ft**	**$363.21**

Figure C.9 Cost Distribution of Selected Group Elements and Individual Elements for the Gateway Arch Bridge



Source: Alfred Benesch & Company

Table C.3 is organized so that the costs from each lower level in the UNIFORMAT II hierarchy can be easily aggregated. The first four columns correspond to Levels 1, 2, 3, and 4 of the proposed UNIFORMAT II elemental classification. The last five columns list any Level 5 Sub Elements, as well as item alphanumeric designation and name, quantities, units of measure, unit costs, and item cost. Two intermediate columns summarize the cost characteristics of each Level 4 Sub Element. In several cases—B3020 Wearing Surface—the entries correspond to the Level 3 Individual element. The two intermediate columns show the cost of the Level 4 Sub Element, which is obtained by summing over all Level 5 Sub Elements associated with that Level 4 Sub Element, and the per cent of total cost associated with that cost. For example, the Level 4 Sub Element, A301020 Piles, has a cost of $269 000. Given that the total cost of the bridge is $6.76 million, this value represents 4.03 % of the total cost.

The cost of a Level 3 Individual Element is obtained by summing over all of its Level 4 Sub Elements. In a similar fashion, the cost of a Level 2 Group Element is obtained by summing over all of its Level 3 Individual Elements and the cost of a Level 1 Major Group Element is obtained by summing over all of its Level 2 Group Elements. The cost for each Major Group Element and Group Element, along with its per cent of total cost and unit cost, are recorded in the first two columns of Table C.3. Note that some Group Elements have a single Level 3 Individual Element. For example, Group Element A40, Other Supports, has a single Individual Element, A4010 Thrust Blocks. In such cases the values recorded under the Level 2 Group Element heading correspond to those associated with the Level 3 Individual Element.

The values recorded in Table C.3 provide the basis for Figure C.9. Figure C.9 presents a cost distribution of selected Group Elements and Individual Elements tied to a graphical representation of a longitudinal view of the Gateway Arch Bridge. The figure includes the alphanumeric string, the name of the Group Element or Individual Element, its cost, and its per cent of total cost. Two Group Elements and six Individual Elements are highlighted in Figure C.9. Reference to Figure C.9 reveals that the Level 2 Group Element A30 Abutment has a cost of $824 000, which corresponds to 12.3 % of the total cost. The other Level 2 Group Element shown in Figure C.9, B30 Deck, has a cost of $658 000 or 9.9 % of total cost. Two Individual Elements, B1010 Flexural Members and B2010 Ribs, are of particular importance, since they each represent more than 20 % of the total cost of the bridge. Table C.3 and Figure C.9 illustrate how the proposed UNIFORMAT II elemental classification can be used to focus attention on those elements that drive the overall costs of a bridge project, as well as those elements that are associated with special characteristics—in this case the unique foundation system—of a particular bridge.

The Gateway Arch Bridge won six awards, including two national awards. The two national awards were the 2006 Outstanding Project Award from the National Council of structural Engineers Association and the 2007 Prize Bridge—Medium Span Award from the National Steel Bridge Alliance. In addition to the two national awards, the Gateway Arch Bridge won the 2006 Best Medium Structure Award from the Structural Engineers Association of Illinois; the 2006 Engineering Honorable Conceptor Award from the

Michigan Chapter of the American Council of Engineering Companies; the 2008 Partnering Award from the Michigan Construction Quality Partnership; and the 2008 Making a Difference Gold Award for Partnering from the National Partnership for Highway Quality. A major criterion for its selection as an award recipient was its cost effectiveness.