



Standard Classification for Bridge Elements—UNIFORMAT II¹

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1. Scope

1.1 This standard establishes a classification of bridge elements within the UNIFORMAT II family of elemental classifications. It covers most highway bridges, railroad bridges, and pedestrian bridges.

1.2 UNIFORMAT II classifications have an elemental format similar to the original UNIFORMAT² 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.

1.3 Elements, as defined here and in other UNIFORMAT II Classifications, 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.

1.4 This elemental classification serves as a consistent reference for analysis, evaluation, and monitoring during the feasibility, planning, and design stages when constructing bridges.

1.5 Using UNIFORMAT II elemental classifications ensures a consistency in the economic evaluation of construction projects over time and from project to project.

1.6 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.

1.7 This classification is unsuitable for process applications or for preparing trade estimates.

1.8 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each

system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.9 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:³

- E631 Terminology of Building Constructions
- E833 Terminology of Building Economics
- E917 Practice for Measuring Life-Cycle Costs of Buildings and Building Systems
- E964 Practice for Measuring Benefit-to-Cost and Savings-to-Investment Ratios for Buildings and Building Systems
- E1057 Practice for Measuring Internal Rate of Return and Adjusted Internal Rate of Return for Investments in Buildings and Building Systems
- E1074 Practice for Measuring Net Benefits and Net Savings for Investments in Buildings and Building Systems
- E1121 Practice for Measuring Payback for Investments in Buildings and Building Systems
- E1185 Guide for Selecting Economic Methods for Evaluating Investments in Buildings and Building Systems
- E1369 Guide for Selecting Techniques for Treating Uncertainty and Risk in the Economic Evaluation of Buildings and Building Systems
- E1699 Practice for Performing Value Analysis (VA) of Buildings and Building Systems and Other Constructed Projects
- E1804 Practice for Performing and Reporting Cost Analysis During the Design Phase of a Project
- E1946 Practice for Measuring Cost Risk of Buildings and Building Systems and Other Constructed Projects
- E2013 Practice for Constructing FAST Diagrams and Performing Function Analysis During Value Analysis Study

¹ This classification is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.81 on Building Economics.

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² The original UNIFORMAT classification was developed jointly by the General Services Administration (GSA) and the American Institute of Architects (AIA).

³ For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.



E2506 Guide for Developing a Cost-Effective Risk Mitigation Plan for New and Existing Constructed Facilities

E2691 Practice for Job Productivity Measurement

2.2 *ASTM UNIFORMAT II Classification Standards Family*.³

E1557 Classification for Building Elements and Related Sitework—UNIFORMAT II

E2083 Classification for Building Construction Field Requirements, and Office Overhead & Profit

E2168 Classification for Allowance, Contingency, and Reserve Sums in Building Construction Estimating

E2514 Practice for Presentation Format of Elemental Cost Estimates, Summaries, and Analyses

E2516 Classification for Cost Estimate Classification System

2.3 *ASTM Adjuncts*.⁴

Discount Factor Tables Adjunct to Practices E917, E964, E1057, E1074, and E1121

3. Terminology

3.1 *Definitions*—For definitions of general terms related to building construction used in this classification, refer to Terminology **E631**, and for general terms related to building economics, refer to Terminology **E833**.

4. Significance and Use

4.1 This standard builds on the concepts and organizational framework first established in Classification **E1557**. This classification describes bridge elements that are major components of most highway, railroad, and pedestrian bridges. The elemental classification is the common thread linking activities and participants in a bridge project from initial planning through operations, maintenance, and disposal.

NOTE 1—As this classification refers solely to permanent, physical parts of any construction, two additional classifications, Classifications **E2083** and **E2168**, 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 described in Practices **E1804** and **E2514** and Classification **E2516**. 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.

4.2 *The Users of Bridge UNIFORMAT II Include:*

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

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

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

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

4.3 *Apply This Classification When Undertaking the Following Work on Bridges*.⁵

4.3.1 *Financing and Investing:*

4.3.1.1 Structuring costs on an elemental basis for economic evaluations (Guide **E1185** and Practices **E917**, **E964**, **E1057**, **E1074**, **E1121**, and **E1804**) early in the design process helps reduce the cost of early financial analysis and can contribute to substantial design and operational savings before decisions have been made that limit options for potential savings.

4.3.2 *Implementing:*

4.3.2.1 *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.

4.3.2.2 *Conducting Value Engineering Workshops*—Conducting value engineering workshops (Practices **E1699** and **E2013**). 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.

4.3.2.3 *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 (Practice **E2691**), and to set milestone target dates.

4.3.2.4 *Performing Risk Analyses—Simulation* (Guides **E1369** and **E2506**) 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 (Practices **E1946** and **E2168**) or to serve as inputs to an economic analysis.

4.3.2.5 *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.

4.3.2.6 *Coding and Referencing Standard Details In Computer-Aided Design Systems*—This classification allows a designer, for example, to reference an assembly according to

⁴ Available from ASTM International Headquarters. Order Adjunct No. ADJE091703. Original adjunct produced in 1984. Adjunct last revised in 1985.

⁵ For a more comprehensive discussion of the uses of UNIFORMAT II, see Bowen, Charette, and Marshall, *UNIFORMAT II—A Recommended Classification for Building Elements and Related Sitework*, National Institute of Standards and Technology Special Publication 841, Gaithersburg, MD, 1992; and Charette and Marshall, *UNIFORMAT II Elemental Classification for Building Specifications, Cost Estimating, and Cost Analysis*, National Institute of Standards and Technology NISTIR 6389, Gaithersburg, MD, 1999.

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.

4.3.3 Managing Facilities:

4.3.3.1 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.

4.3.4 Other Activities:

4.3.4.1 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.

5. Basis of Classification

5.1 The framework in Fig. 1 shows the various constructed entities that collectively are used to create the built environment. Each entity is treated as a module. Appropriate modules used together will effectively describe any planned or built development. This standard classification 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.

5.1.1 This bridge classification is applicable to most types of highway, railroad, and pedestrian bridges crossing over highways, railroads, walkways, and waterways. 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.

5.2 The classification is consistent with typical costing practices used at the conceptual design phase.

5.3 Each element has a significant impact on the cost, and it usually occurs frequently.

5.4 Each element performs a specific function.

5.5 Table 1 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.

5.6 Sub-Classifications 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. Appendix X1 provides an example Sub-Classification of bridge elements.

5.7 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.

5.8 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, this classification does

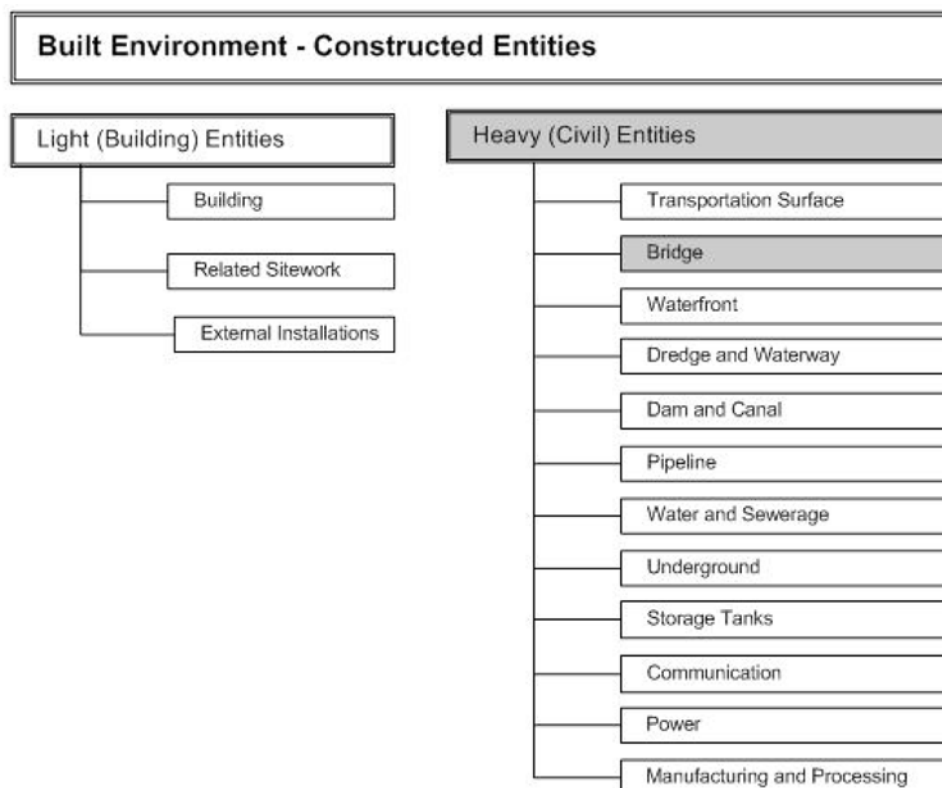


FIG. 1 List of Constructed Entities Suitable for Inclusion in the Family of UNIFORMAT II Elemental Classifications



TABLE 1 UNIFORMAT II Classification of Bridge Elements

Level 1 Major Group Elements	Level 2 Group Elements	Level 3 Individual Elements
Substructure	Piers	Foundations Walls Columns Cap Beams
	Towers	Foundations Walls Columns Cap Beams
	Abutments	Foundations Stems Wing Walls
	Other Supports	Thrust Blocks Anchorages
Superstructure	Short Span Assemblies	Flexural Members Diaphragms Bracings Bearings
	Long Span Assemblies	Ribs Cables Hangers Spandrels Ties Truss Members Segmental Box Girders
	Deck	Structural Surface Wearing Surface
Protection	Structure Protection	Slope Walls Expansion Joints Protective Coats Sacrificial Beams Drainage Systems Inspection and Maintenance Systems
	Traffic Protection	Barriers Protective Shields Traffic Controls
	Other Protection	Lighting Signage Sound Barrier Walls Air Pressure Barriers Enclosure
Sitework	Site Preparation	Clearing and Grubbing Demolition and Relocation Earthwork Hazardous Material Handling Environmental Restoration/Replacement
	Approach Construction	Approach Slabs Sleeper Slabs Earth Retention Systems

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.

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

- 5.9.1 Capable of being defined precisely;
- 5.9.2 Self explanatory;
- 5.9.3 Separable at all stages of development;
- 5.9.4 Quantifiable at all stages of development;
- 5.9.5 Capable of reconciliation with other elemental classifications;
- 5.9.6 Allow comparisons, project to project, in a meaningful way;
- 5.9.7 Is a functional component of the constructed entity.

5.10 Sitework elements are provided for exclusive use in support of the construction of bridges, not to classify elements of major civil construction works. Sitework elements presented in Table 1 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.

6. Description of Project Elements

6.1 *Elements and Functions*—Table 2 provides, for each Level 3 Individual Element, the name, functions, description, inclusions, exclusions, and unit of measure. 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.



TABLE 2 Description of UNIFORMAT II Bridge Elements

SUBSTRUCTURE	
Piers	
	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]
	Walls
Primary Function	Distribute load, Protect foundation
Secondary Function	Enhance appearance
Tertiary Function	Expedite construction
Description	Walls are structures that support 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	
Excludes	
Unit of Measure	m ³ [yd ³] or kg [lb]
	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]
	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]
SUBSTRUCTURE	
Towers	
	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]
	Walls
Primary Function	Distribute load, Protect foundation
Secondary Function	Enhance appearance
Tertiary Function	Expedite construction
Description	Walls are structures that support 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	
Excludes	
Unit of Measure	m ³ [yd ³] or kg [lb]
	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	

TABLE 2 Continued

Excludes	
Unit of Measure	m ³ [yd ³] or kg [lb]
	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]
SUBSTRUCTURE	
Abutments	
	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]
	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, and anchor bolts and bearings (see Foundations, Barriers, Slope Wall, Bearings)
Unit of Measure	m ³ [yd ³] or kg [lb]
	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]
SUBSTRUCTURE	
Other Supports	
	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]
	Anchorage
Primary Function	Secure cable, Transfer load
Secondary Function	Maintain even distribution
Tertiary Function	
Description	Anchorage 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]



TABLE 2 Continued

SUPERSTRUCTURE Short Span Assemblies	
	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 and girders
Excludes	Diaphragms, bracings, bearings (see Diaphragms, Bracings, Bearings)
Unit of Measure	kg [lb] or m [ft]
	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]
	Bracings
Primary Function	Stabilize girders
Secondary Function	Facilitate deck reconstruction
Tertiary Function	
Description	Bracings are steel angles used to brace deep-depth girders.
Includes	Fabrication and erection of structural steel angles
Excludes	
Unit of Measure	kg [lb]
	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, whereas fixed bearings allow only rotational movement.
Includes	Fabrication and erection of bearings and anchor bolts
Excludes	Bridge seat (see Cap Beams, Stem Abutments)
Unit of Measure	EACH
SUPERSTRUCTURE Long Span Assemblies	
	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	
Excludes	Bracings, bearings (see Bracings, Bearings)
Unit of Measure	kg [lb], or m ³ [yd ³], or m [ft]
	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 hangars the load from the deck.
Includes	Fabrication and installation of cables, cable support
Excludes	Anchorage (see Anchorage)
Unit of Measure	m [ft]
	Hangers
Primary Function	Transfer load
Secondary Function	Increase vertical clearance
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]

TABLE 2 Continued

Spandrels	
Primary Function	Transfer load
Secondary Function	Increase reliability
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]
	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, bearings (see Bearings, Hangers and Spandrels)
Unit of Measure	kg [lb]
	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]
	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]
SUPERSTRUCTURE Deck	
	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 Systems)
Unit of Measure	m ³ [yd ³] or EACH
	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, marking,
Excludes	
Unit of Measure	m ² [yd ²]
PROTECTION Structure Protection	
	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)



TABLE 2 Continued

Unit of Measure	m ² [yd ²]
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]
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 [yd ²]
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]
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]
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 [yd ²]
PROTECTION	
Traffic Protection	
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, or light pole support
Excludes	
Unit of Measure	m ³ [yd ³]
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 [yd ²]
Traffic Controls	

TABLE 2 Continued

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	
Unit of Measure	EACH
PROTECTION	
Other Protection	
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
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
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 [yd ²]
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 [yd ²]
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 with expansion joints at the ends
Excludes	
Unit of Measure	m ² [yd ²]
SITWORK	
Site Preparation	
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)
Demolition and Relocation	



TABLE 2 Continued

Primary Function	Eliminate obstacles
Secondary Function	Protect structures
Tertiary Function	Protect environment
Description	Demolition is the complete or partial (for example, 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
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]
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]
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)
SITWORK	
Approach Construction	
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	Granular fill, drain tiles, concrete, reinforcing, and finishing
Excludes	Barrier and wing wall (see Barriers, Wing Walls)
Unit of Measure	m ² [yd ²]
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, reinforcing and finishing
Excludes	Approach slab (see Approach Slabs)
Unit of Measure	m ³ [yd ³]
Earth Retention Systems	
Primary Function	Retain embankment
Secondary Function	Enhance appearance
Tertiary Function	Facilitate construction

TABLE 2 Continued

Description	Earth retention systems are designed to support embankments when the grades are not uniform.
Includes	Its foundation and wall
Excludes	Excavation and backfill (see Earthwork)
Unit of Measure	m ³ [yd ³] or m ² [yd ²]

6.2 Description—The element descriptions help you understand the purpose and application of the element.

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

6.4 Excludes—The purpose of the element exclusions is to list features that are not included in the element but which are included elsewhere in this classification.

NOTE 2—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.

6.5 Unit of Measure—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 inch-pound units are reported. SI units are reported first followed by inch-pound units within brackets. Table 2 uses the following unit of measure abbreviations: linear metres (m) and linear feet (ft); square metres (m²) and square feet (ft²); cubic metres (m³) and cubic yards (yd³); and kilograms (kg) and pounds (lb).

7. Application

7.1 **Appendix X2** uses a case study of the Gateway Arch Bridge construction project to demonstrate how to use the Classification E2103 and the example Sub-Classification to analyze and manage bridge design and construction costs. The Gateway Arch Bridge was part of the reconstruction of Interstate 94 for the Super Bowl XL game held in 2006.⁶

8. Keywords

8.1 bridge assemblies; bridge cost estimation; bridge cost planning; bridge elemental format; bridge elements; bridge functional elements; bridge systems classification; construction; design economics; economic analysis; economic evaluation; elemental bridge classification; elemental/systems classification; life-cycle costing; master schedules; outline specifications; preliminary project description; risk analysis; sitework; standard classifications of bridge systems; UNIFORMAT II; value engineering

⁶ For a comprehensive discussion of the uses of ASTM Building Economics Standards to design and construction applications in general and to the Gateway Arch Bridge in particular, see Kasi and Chapman, *Benefits of Using ASTM Building Economics Standards for the Design, Construction, and Operation of Constructed Facilities*, National Institute of Standards and Technology, Special Publication 1098, Gaithersburg, MD, 2012.

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLE SUB-CLASSIFICATION OF BRIDGE ELEMENTS

X1.1 This appendix presents an example Sub-Classification of bridge elements. The Sub-Classification expands the Classification E2103 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.

X1.2 The example Sub-Classification is presented in **Table X1.1. Table X1.1** is laid out in a five-column format. The first column lists the Level 1 Major Group Elements. The second column lists the Level 2 Group Elements associated with each Level 1 Major Group Element. The third column lists the Level 3 Individual Elements associated with each Level 2 Group Element. 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.

X1.3 Alphanumeric designators are included for all Level 1 Major Group Elements, Level 2 Group Elements, Level 3 Individual Elements, Level 4 Sub-Elements, and Level 5 Sub-Elements. 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.

X1.4 Alphanumeric designators for the Classification E2103 presented in this appendix use a format similar to that employed in Classification **E1557**. Specifically, the format for the alphanumeric designators is as follows: Level 1, Major Group Elements, use a single capital letter; Level 2, Group Elements, use a two-digit number preceded by the Level 1 letter; and Level 3, Individual Elements, use a two-digit number preceded by the Level 2 character string.

X1.5 The alphanumeric designators for the example Sub-Classification uses 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 character string 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.



TABLE X1.1 Example Sub-Classification of Bridge Elements

Level 1 Major Group Elements	Level 2 Group Elements		Level 3 Individual Elements		Level 4 Sub-Elements		Level 5 Sub-Elements					
A Substructure	A10	Piers	A1010	Foundation	A101010	Spread Footings	A10101010	Excavation				
							A10101020	Reinforcement				
							A10101030	Placement				
							A10101040	Backfilling				
					A101020	Piles	A10102010	Test Piles				
							A10102020	Piles				
							A10102030	Pile Cap				
							A10103010	Permanent Casing				
					A101030	Drilled Shafts	A10103020	Rock Socket				
							A10103030	Bell				
							A10103040	Reinforcement				
							A10103050	Placement				
					A10103060	Cap						
			A1020	Walls	A102010	Cast-in-Place Concrete	A10201010	Reinforcement				
							A10201020	Placement				
							A10201030	Finishing				
							A10201040	Coating				
			A102020	Precast Concrete	A10202010	Fabrication	A10202020	Erection				
							A10301010	Reinforcement				
							A10301020	Placement				
							A10301030	Finishing				
			A1030	Columns	A103010	Cast-in-Place Concrete	A10302010	Fabrication				
							A10302020	Erection				
							A10303010	Fabrication				
					A103020	Precast Concrete	A10303020	Erection				
							A10304010	Fabrication				
							A10304020	Erection				
					A103030	Steel	A10401010	Reinforcement				
							A10401020	Placement				
							A10401030	Finishing				
			A1040	Cap Beams	A104020	Precast Concrete	A10402010	Fabrication				
							A10402020	Erection				
							A10403010	Fabrication				
							A10403020	Erection				
			A104030	Steel	A104040	Timber	A10404010	Fabrication				
							A10404020	Erection				
							A20101010	Excavation				
							A20101020	Reinforcement				
			A20	Towers	A2010	Foundations	A201010	Spread Footings	A20101030	Placement		
	A20101040	Backfilling										
	A20102010	Test Piles										
	A20102020	Piles										
	A20102030	Pile Cap										
	A201030	Drilled Shafts							A20103010	Permanent Casing		
									A20103020	Rock Socket		
									A20103030	Bell		
									A20103040	Reinforcement		
	A20103050	Placement										
	A20103060	Cap										
	A2020	Walls							A202010	Cast-in-Place Concrete	A20201010	Reinforcement
											A20201020	Placement
							A20201030	Finishing				
							A20201040	Coating				
	A202020	Precast Concrete					A20202010	Fabrication	A20202020	Erection		
									A20301010	Reinforcement		
									A20301020	Placement		
									A20301030	Finishing		
	A2030	Columns					A203010	Cast-in-Place Concrete	A20302010	Fabrication		
									A20302020	Erection		
									A20303010	Fabrication		
							A203020	Precast Concrete	A20303020	Erection		
									A20304010	Fabrication		
									A20304020	Erection		
							A203030	Steel	A20401010	Reinforcement		
									A20401020	Placement		
									A20401030	Finishing		
	A2040	Cap Beams					A204020	Precast Concrete	A20402010	Fabrication		
									A20402020	Erection		
									A20403010	Fabrication		
									A20403020	Erection		
	A204030	Steel					A204040	Timber	A20404010	Fabrication		
									A20404020	Erection		
									A20404030	Fabrication		
									A20404040	Fabrication		



TABLE X1.1 Continued

Level 1 Major Group Elements	Level 2 Group Elements	Level 3 Individual Elements	Level 4 Sub-Elements	Level 5 Sub-Elements
B Superstructure	A30 Abutments	A3010 Foundations	A301010 Spread Footings	A20404020 Erection
				A30101010 Excavation
				A30101020 Reinforcement
				A30101030 Placement
				A30101040 Backfilling
				A30102010 Test Piles
		A301020 Piles	A30102020 Piles	A30102030 Pile Cap
			A30103010 Permanent Casing	A30103020 Rock Socket
			A30103030 Bell	A30103040 Reinforcement
			A30103050 Placement	A30103060 Cap
		A3020 Stems	A30201010 Reinforcement	A30201020 Placement
			A30201030 Finishing	A30202010 Fabrication
			A30202020 Erection	A30301010 Reinforcement
		A3030 Wing Walls	A30301020 Placement	A30301030 Finishing
			A30302010 Fabrication	A30302020 Erection
			A30302020 Erection	A40101010 Reinforcement
			A40101020 Placement	A40101030 Finishing
	A40 Other Supports	A4010 Thrust Blocks	A401010 Cap	A40102010 Spread Footings
				A40102020 Piles
				A40102030 Drilled Shafts
				A40201010 Spray Saddle
			A402010 Prestressed	A40201020 Anchor
				A40202010 Reinforcement
				A40202020 Placement
				A40203010 Spread Footings
			A402020 Cast-in-Place Concrete	A40203020 Piles
				A40203030 Drilled Shafts
		A402030 Foundations	A40203020 Piles	A40203030 Drilled Shafts
			A40203030 Drilled Shafts	B10101010 Reinforcement
B Superstructure	B10 Short Span Assemblies	B1010 Flexural Members	B101010 Cast-in-Place Concrete	B10101020 Placement
				B10101030 Finishing
				B10102010 Fabrication
				B10102020 Erection
		B101020 Precast Concrete	B10103010 Fabrication	B10103020 Erection
			B10104010 Fabrication	B10104020 Erection
		B101030 Steel	B10201010 Reinforcement	B10201020 Placement
			B10202010 Fabrication	B10202020 Erection
			B10203010 Fabrication	B10203020 Erection
			B10203020 Erection	B10203030 Erection
		B1020 Diaphragms	B10201010 Reinforcement	B10201020 Placement
			B10202010 Fabrication	B10202020 Erection
			B10203010 Fabrication	B10203020 Erection
			B10203020 Erection	B10301010 Fabrication
		B1030 Bracings	B10301020 Erection	B10301030 Fabrication
			B10301030 Fabrication	B10301040 Erection
			B10302010 Fabrication	B10302020 Erection
			B10302020 Erection	B10302030 Erection
	B20 Long Span Assemblies	B2010 Ribs	B201010 Cast-in-Place Concrete	B20101010 Reinforcement
				B20101020 Placement
				B20102010 Fabrication
				B20102020 Erection
			B201020 Precast Concrete	B20103010 Fabrication
				B20103020 Erection
		B2020 Cables	B202010 Wires	B20201010 Reinforcement
				B20201020 Placement
				B20202010 Fabrication
				B20202020 Erection
				B20203010 Fabrication
				B20203020 Erection
	B2030 Hangers	B203010 Top Anchor Socket	B203010 Top Anchor Socket	B20301010 Reinforcement
				B20301020 Placement
				B20301030 Finishing
				B20301040 Backfilling
				B20301050 Test Piles
				B20301060 Piles



TABLE X1.1 Continued

Level 1 Major Group Elements	Level 2 Group Elements	Level 3 Individual Elements	Level 4 Sub-Elements	Level 5 Sub-Elements
			B203020 Strand B203030 Rod B203040 Boot B203050 Spacer B203060 Bottom Anchor Socket	
		B2040 Spandrels	B204010 Cast-in-Place Concrete B204020 Precast Concrete B204030 Steel	B20401010 Reinforcement B20401020 Placement B20401030 Finishing B20402010 Fabrication B20402020 Erection B20403010 Fabrication B20403020 Erection
		B2050 Ties	B205010 Cast-in-Place Concrete B205020 Precast Concrete B205030 Steel B205040 Splices B205050 Connections	B20501010 Reinforcement B20501020 Placement B20502010 Fabrication B20502020 Erection B20503010 Fabrication B20503020 Erection
		B2060 Truss Members	B206010 Members B206020 Splices B206030 Connections	
		B2070 Segmental Box Girders	B207010 Main Members B207020 Placement	B20702010 Erection B20702020 Permanent Post Tensioning B20702030 Closure Piece Placement
	B30 Deck	B3010 Structural Surface	B301010 Cast-in-Place Concrete B301020 Precast Concrete B301030 Steel B301040 Timber	B30101010 Reinforcement B30101020 Placement B30101030 Finishing B30102010 Fabrication B30102020 Erection B30103010 Metal Deck B30103020 Connections B30104010 Plank B30104020 Connections
		B3020 Wearing Surface	B302010 Cast-in-Place Concrete B302020 Asphalt B302030 Rails	B30201010 Placement B30201020 Finishing B30202010 Placement B30202020 Finishing
C Protection	C10 Structure Protection	C1010 Slope Walls	C101010 Cast-in-Place Concrete C101020 Asphalt C101030 Stone	C10101010 Reinforcement C10101020 Placement C10101030 Finishing C10102010 Gravel C10102020 Placement
		C1020 Expansion Joints	C102010 Strip-Seal C102020 Modular C102030 Finger Plate	
		C1030 Protective Coats	C103010 Preparation C103020 Application	
		C1040 Sacrificial Beams	C104010 Fabrication C104020 Erection	
		C1050 Drainage Systems	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	



TABLE X1.1 Continued

Level 1 Major Group Elements	Level 2 Group Elements	Level 3 Individual Elements	Level 4 Sub-Elements	Level 5 Sub-Elements
D Sitework	C30 Other Protection	C2020 Protective Shields	C201070	Screen
			C202010	Fabrication
			C202020	Erection
		C2030 Traffic Controls	C203010	Signals
			C203020	Arms
			C203030	Mast
			C203040	Base Plate
			C203050	Conduits
		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
		D1050 Environmental Restoration/Replacement	D105010	Environmental Restoration
			D105020	Environmental Replacement
	D20 Approach Construction	D2010 Approach Slabs	D201010	Reinforcement
			D201020	Placement
			D201030	Finishing
		D2020 Sleeper Slabs	D202010	Excavation
			D202020	Reinforcement
			D202030	Placement
			D202040	Backfilling
		D2030 Earth Retention Systems	D203010	Foundation
			D203020	Wall
			D203030	Cap

X2. CASE ILLUSTRATIONS TO A SINGLE-SPAN, MODIFIED TIED-ARCH BRIDGE

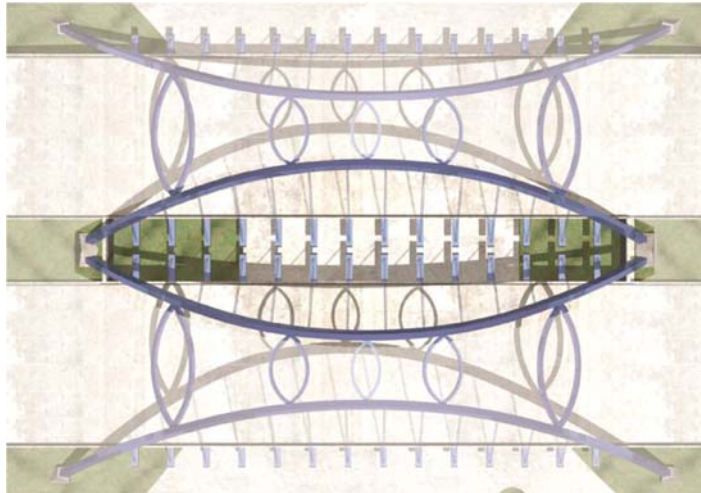
X2.1 Summary of Key Bridge Characteristics

X2.1.1 The material presented in this appendix is abstracted from NIST Special Publication 1098.⁷ This appendix uses a case study bridge construction project to demonstrate how to use the Classification E2103 and example Sub-Classification in conjunction with Practice E2013 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. Fig. X2.1 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. Fig. X2.2 and Fig. X2.3 provide different perspectives of the bridge as seen from Telegraph Road (Fig. X2.2) and from I-94 (Fig. X2.3).

X2.1.2 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

⁷ Kasi and Chapman, *Benefits of Using ASTM Building Economics Standards for the Design, Construction, and Operation of Constructed Facilities*, National Institute of Standards and Technology, Special Publication 1098, Gaithersburg, MD, 2012.



Source: Alfred Benesch & Company

FIG. X2.1 Overhead View of the Gateway Arch Bridge



Source: Alfred Benesch & Company

FIG. X2.2 Gateway Arch Bridge as Seen from Telegraph Road

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.

X2.1.3 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 Practice E2013. 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 were identified, the team developed

innovative solutions to create value of the elements that had a higher need/performance at a comparable or lower cost.

X2.1.4 Through repeated use of Practice E2013 the project team was able to develop and implement five key design innovations that balanced safety and aesthetics with life-cycle cost considerations. The five key design innovations are: (1) unique foundation system composed of longitudinal and transverse foundation ties and battered piles; (2) inclined arch ribs of unequal lengths that make the bridge appear as a true arch; (3) pressurized arch ribs to minimize future maintenance costs; (4) dual strand hanger assemblies to provide redundancy and



Source: Alfred Benesch & Company

FIG. X2.3 Gateway Arch Bridge as Seen from I-94

facilitate the replacement of individual strands; and (5) transverse girders composed of a plate girder in the middle and a box section on the ends for torsional stiffness.

X2.2 Cost Analysis of the Gateway Arch Bridge Using the UNIFORMAT II Elemental Classification and Example Sub-Classification

X2.2.1 The total contract award cost for one of the two bridge structures making up the Gateway Arch Bridge is \$6.67 million. Since the two bridge structures are identical, their total contract award cost is \$13.34 million. The cost analysis of the Gateway Arch Bridge using the Classification E2103 and example Sub-Classification is presented in Fig. X2.4 and summarized in Fig. X2.5. Fig. X2.4 records information for each of the three levels in the Classification E2103 and the two additional levels in the example Sub-Classification. Fig. X2.4 includes alphanumeric designations and Element/Sub-Element names, dollar values, and percent of total cost associated with those dollar values. Fig. X2.5 records the cost distribution of selected Group Elements and Individual Elements. The costs summarized in Fig. X2.5 are the major Substructure and Superstructure Group Elements and Individual Elements; they account for approximately 85 % of the Gateway Arch Bridge's total cost.

X2.2.2 Fig. X2.4 is organized so that the costs from each lower level in the UNIFORMAT II hierarchy can be easily aggregated. The first three columns correspond to Levels 1, 2, and 3 of the Classification E2103. The fourth column corresponds to Level 4 of the example Sub-Classification. The fifth column lists detailed cost information, including any Level 5 Sub-Elements of the example Sub-Classification. In several cases, the entries under the Detailed Cost Information heading correspond to a Level 4 Sub-Element or a Level 3 Individual Element. Two intermediate columns under the Detailed Cost Information heading report the percent of total cost and the cost for each detailed cost item. The cost of each Level 4 Sub-

Element is obtained by summing over all Level 5 Sub-Elements associated with it. The two intermediate columns under the Level 4 heading summarize the cost characteristics of each Level 4 Sub-Element, specifically the per cent of total cost and the cost associated with that Sub-Element. For example, the Level 4 Sub-Element, A301020 Piles, has a cost of \$269 000. Given that the total cost of the bridge is \$6.67 million, this value represents 4.03 % of the total cost.

X2.2.3 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, are recorded in the first two columns of Fig. X2.4. 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.

X2.2.4 The values recorded in Fig. X2.4 provide the basis for Fig. X2.5. Fig. X2.5 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 Fig. X2.5. Reference to Fig. X2.5 reveals that the Level 2 Group Element A30 Abutments has a cost of \$824 000, which corresponds to 12.3 % of the total cost. The other Level 2 Group Element shown in Fig. X2.5, B30 Deck, has a cost of \$658 000 or 9.9 % of total cost. Two Individual Elements, B1010 Flexural Members and B2010



Level 1		Level 2		Level 3		Level 4		Detailed Cost Information				
Major Group Elements		Group Elements		Individual Elements	% Total Cost	Cost	Level 4 Sub-Elements	% Total Cost	Cost			
A Substructure	\$1,369,210	20.5%	12.3%	A30 Abutments								
				\$823,485			A3010 Foundation	4.03%	\$268,875	A301020 Piles	4.03%	\$268,875
										A10102030 Pile Cap	0.61%	\$40,500
										A30201010 Reinforcement	1.06%	\$70,650
										A30201020 Placement	7.06%	\$471,000
B Superstructure	\$4,493,274	67.3%	26.6%	A40 Other Supports								
				\$545,725						A30301010 Reinforcement	0.04%	\$2,560
										A30301010 Placement	0.16%	\$10,400
										A40101010 Reinforcement	0.95%	\$63,175
										A40101020 Placement	4.06%	\$270,750
C Protection	\$186,440	2.8%	0.1%	B10 Short span assemblies								
				\$1,772,355						A401020 Foundations	3.17%	\$211,800
										B10103010 Fabrication	12.78%	\$852,749
										B10103020 Erection	9.58%	\$639,362
										B10203010 Fabrication	0.63%	\$42,000
D Sitemap	\$624,998	9.4%	8.6%	B20 Long Span Assemblies								
				\$2,063,325						B10203020 Erection	0.47%	\$31,500
										B10301010 Fabrication	1.20%	\$79,933
										B10301020 Erection	1.00%	\$66,611
										B20103010 Fabrication	0.90%	\$60,000
E Protection	\$186,440	2.8%	0.1%	B30 Deck								
				\$657,594						B20103010 Fabrication	11.95%	\$797,567
										B20103020 Erection	9.96%	\$664,639
										B20501010 Reinforcement	5.25%	\$350,450
										B20501020 Placement	0.89%	\$59,569
F Protection	\$186,440	2.8%	0.1%	B3020 Wearing Surface								
										B20501020 Placement	2.86%	\$191,100
										B30101010 Reinforcement	2.51%	\$167,344
										B30101020 Reinforcement	4.63%	\$308,750
										B30101020 Placement	2.72%	\$181,500
G Protection	\$186,440	2.8%	0.1%	C10 Structure Protection								
				\$4,000								\$4,000
H Protection	\$186,440	2.8%	0.1%	C20 Traffic protection								
				\$57,440								\$33,000
I Protection	\$186,440	2.8%	0.1%	C30 Other Protection								
				\$125,000								\$125,000
J Protection	\$186,440	2.8%	0.1%	D10 Site Preparation								
				\$572,938								\$65,000
K Protection	\$186,440	2.8%	0.1%	D20 Approach Construction								
				\$52,060								\$48,060
L Protection	\$186,440	2.8%	0.1%	D30 Slope Protection								
				\$52,060								\$48,060
M Protection	\$186,440	2.8%	0.1%	D40 Slope Protection								
				\$52,060								\$48,060
N Protection	\$186,440	2.8%	0.1%	D50 Slope Protection								
				\$52,060								\$48,060
O Protection	\$186,440	2.8%	0.1%	D60 Slope Protection								
				\$52,060								\$48,060
P Protection	\$186,440	2.8%	0.1%	D70 Slope Protection								
				\$52,060								\$48,060
Q Protection	\$186,440	2.8%	0.1%	D80 Slope Protection								
				\$52,060								\$48,060
R Protection	\$186,440	2.8%	0.1%	D90 Slope Protection								
				\$52,060								\$48,060
S Protection	\$186,440	2.8%	0.1%	D100 Slope Protection								
				\$52,060								\$48,060
T Protection	\$186,440	2.8%	0.1%	D110 Slope Protection								
				\$52,060								\$48,060
U Protection	\$186,440	2.8%	0.1%	D120 Slope Protection								
				\$52,060								\$48,060
V Protection	\$186,440	2.8%	0.1%	D130 Slope Protection								
				\$52,060								\$48,060
W Protection	\$186,440	2.8%	0.1%	D140 Slope Protection								
				\$52,060								\$48,060
X Protection	\$186,440	2.8%	0.1%	D150 Slope Protection								
				\$52,060								\$48,060
Y Protection	\$186,440	2.8%	0.1%	D160 Slope Protection								
				\$52,060								\$48,060
Z Protection	\$186,440	2.8%	0.1%	D170 Slope Protection								
				\$52,060								\$48,060
AA Protection	\$186,440	2.8%	0.1%	D180 Slope Protection								
				\$52,060								\$48,060
AB Protection	\$186,440	2.8%	0.1%	D190 Slope Protection								
				\$52,060								\$48,060
AC Protection	\$186,440	2.8%	0.1%	D200 Slope Protection								
				\$52,060								\$48,060
AD Protection	\$186,440	2.8%	0.1%	D210 Slope Protection								
				\$52,060								\$48,060
AE Protection	\$186,440	2.8%	0.1%	D220 Slope Protection								
				\$52,060								\$48,060
AF Protection	\$186,440	2.8%	0.1%	D230 Slope Protection								
				\$52,060								\$48,060
AG Protection	\$186,440	2.8%	0.1%	D240 Slope Protection								
				\$52,060								\$48,060
AH Protection	\$186,440	2.8%	0.1%	D250 Slope Protection								
				\$52,060								\$48,060
AI Protection	\$186,440	2.8%	0.1%	D260 Slope Protection								
				\$52,060								\$48,060
AJ Protection	\$186,440	2.8%	0.1%	D270 Slope Protection								
				\$52,060								\$48,060
AK Protection	\$186,440	2.8%	0.1%	D280 Slope Protection								
				\$52,060								\$48,060
AL Protection	\$186,440	2.8%	0.1%	D290 Slope Protection								
				\$52,060								\$48,060
AM Protection	\$186,440	2.8%	0.1%	D300 Slope Protection								
				\$52,060								\$48,060
AN Protection	\$186,440	2.8%	0.1%	D310 Slope Protection								
				\$52,060								\$48,060
AO Protection	\$186,440	2.8%	0.1%	D320 Slope Protection								
				\$52,060								\$48,060
AP Protection	\$186,440	2.8%	0.1%	D330 Slope Protection								
				\$52,060								\$48,060
AQ Protection	\$186,440	2.8%	0.1%	D340 Slope Protection								
				\$52,060								\$48,060
AR Protection	\$186,440	2.8%	0.1%	D350 Slope Protection								
				\$52,060								\$48,060
AS Protection	\$186,440	2.8%	0.1%	D360 Slope Protection								
				\$52,060								\$48,060
AT Protection	\$186,440	2.8%	0.1%	D370 Slope Protection								
				\$52,060								\$48,060
											</	

FIG. X2.4 Cost Analysis of the Gateway Arch Bridge Using the UNIFORMAT II Elemental Classification and Example Sub-Classification

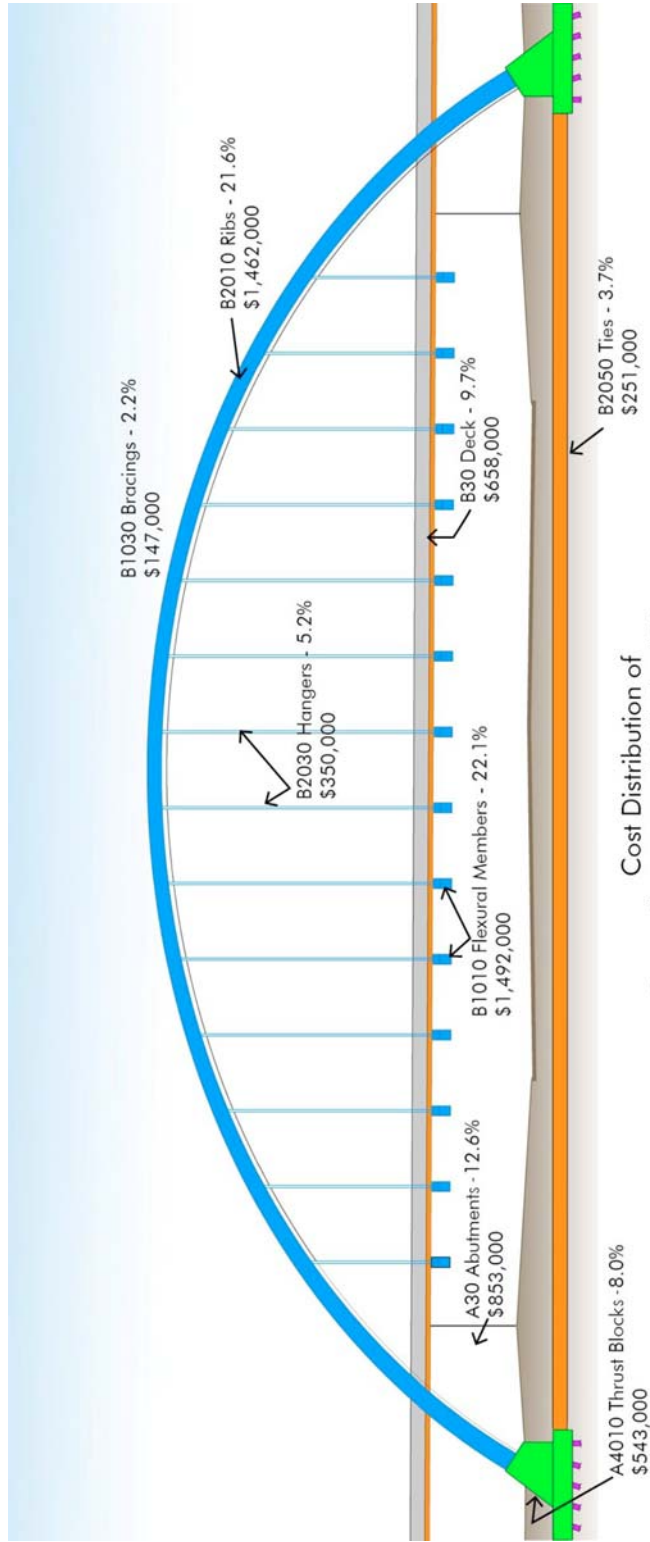


FIG. X2.5 Cost Distribution of Selected Group Elements and Individual Elements for the Gateway Arch Bridge



Ribs, are of particular importance, since they each represent more than 20 % of the total cost of the bridge. Fig. X2.4 and Fig. X2.5 illustrate how the Classification E2103 and example Sub-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 and other design innovations—of a particular bridge.

X2.2.5 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.

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