APPENDIX A

RECOMMENDED MODIFICATIONS TO AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS

SPECIFICATIONS

3.3.2 Load and Load Designation

The following permanent and transient loads, forces, and effects of extreme events shall be considered:

- Permanent Loads

DD = downdrag
DC = dead load of structural components and nonstructural attachments
DW = dead load of wearing surfaces and utilities
EH = horizontal earth pressure load
ES = earth surcharge load
EV= vertical pressure from dead load of earth fill

- Transient Loads

BR = vehicular braking force
CE = vehicular centrifugal force
CR = creep
CT = vehicular collision force
CV = vessel collision force
EQ = earthquake
FR = friction
IC = ice load
IM = vehicular dynamic load allowance
LL = vehicular live load
LS = live load surcharge
PL = pedestrian live load
SC = scour
SE = settlement
SH = shrinkage
TG = temperature gradient
TU = uniform temperature
WA = water load and stream pressure
WL = wind on live load
WS = wind load on structure

3.4 LOAD FACTORS AND COMBINATIONS

3.4.1 Load Factors and Load Combinations

The total factored load shall be taken as:

$$Q = \eta \Sigma \gamma_i q_i \qquad (3.4.1\text{-}1)$$

where:
η = load modifier specified in Article 1.3.2
q_i = loads specified herein
γ_i = load factors specified in Tables 1 and 2

COMMENTARY

Scour is not a load but is an extreme event that alters the geometry of the structure and foundation possibly causing structural collapse or the amplification of the effects of applied loads.

C3.4.1

The background for the load factors specified herein, and the resistance factors specified in other sections of these Specifications are developed in Nowak (1999) and Ghosn, Moses, and Wang (2003).

An alternative formulation that replaces the load modifier by a system factor placed on the left-hand side of the design equation has been proposed by Ghosn and Moses (1998) and Liu, Ghosn, Moses and Neuenhoffer, A. (2001).

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Components and connections of a bridge shall satisfy Equation 1.3.2.1-1 for the applicable combinations of factored extreme force effects as specified at each of the following limit states:

- STRENGTH I-

Basic load relating to vehicular use without wind.

- STRENGTH II -

Load combination relating to the use of the bridge by Owner specified special design vehicles and/or evaluation permit vehicles, without wind.

- STRENGTH III -

Load combination relating to the bridge exposed to wind velocity exceeding 90 km/hr.

- STRENGTH IV -

Load combination relating to very high dead load to live load force effect ratios.

COMMENTARY

A reduced value of 0.50, applicable to all strength load combinations, specified for TU, CR and SH, used when calculating force effects other than displacements at the strength limit state, represents an expected reduction of these force effects in conjunction with the inelastic response of the structure. The calculation of displacements for these loads utilizes a factor greater than 1.0 to avoid undersized joints and bearings. The effect and significance of the temperature gradient remains unclear at this writing. Consult Article C3.12.3 for further information.

The permit vehicle should not be assumed to be the only vehicle on the bridge unless so assured by traffic control. Otherwise, the other lanes should be assumed to be occupied by the vehicular live load as specified herein. For bridges longer than the permit vehicle, the presence of the design lane load, preceding and following the permit load in its lane, should be considered.

Vehicles become unstable at higher wind velocities. Therefore, high winds prevent the presence of significant live load on the bridge.

The standard calibration process for the strength limit state consists of trying out various combinations of load and resistance factors on a number of bridges and their components. Combinations which yield a safety index close to the target value of β = 3.5 are retained for potential application. From these are selected constant load factors γ and corresponding resistance factors β for each type of structural component reflecting its use.

This calibration process had been carried out for a large number of bridges with spans not exceeding 60 000 mm. For the primary components of large bridges, the ratio of dead and live load force effects is rather high, and could result in a set of resistance factors different from those found acceptable for small- and medium-span bridges. It is believed to be more practical to investigate one more load case than to require the use of two sets of resistance factors with the load factors provided in Strength Load Combination I, depending on other permanent loads present. Spot checks had been made on a few bridges with up to 183 000 mm spans, and it appears that Load Combination IV will govern where the dead load to live load force effect ratio exceeds about 7.0.

SPECIFICATIONS

COMMENTARY

- STRENGTH V -

Load combination relating to normal vehicular use of the bridge with wind of 90 km/hr velocity.

- EXTREME EVENT I –

Load combination including earthquake.

This limit state includes live loads, LL in combination with water pressure and earthquakes. The probability of a major earthquake occurring during the crossing of maximum vehicular live loads is small. Hence the use of the 0.25 live load factor is justified.

- EXTREME EVENT II -

Load combination relating to ice load, collision by vessels and vehicles, and to certain hydraulic events with reduced live load, other than that which is part of the vehicular collision load, CT.

The joint probability of these events is extremely low, and, therefore, they are specified to be applied separately. Under these extreme conditions, the structure is expected to undergo considerable inelastic deformation by which locked-in force effects due to TU, TG, CR, SH and SE are expected to be relieved.

The 0.25 live load factor reflects a low probability of the concurrence of the maximum vehicular live load, and the extreme events.

Similarly, a 0.30 wind load factor reflects a low probability of the occurrence of maximum wind speeds and the extreme events.

Because of the very low probability of simultaneous occurrence of large live loads, high winds, and the extreme events, the designer does not need to account for the simultaneous combination of all three effects.

- EXTREME EVENT III

Load combination relating to live load and scour.

A check of the safety of the foundation should first be performed by multiplying the scour depth calculated from the HEC-18 equations by a scour safety factor equal to 2.00. This 2.00 factor ensures that bridges susceptible to scour will still have reliability levels similar to those of other bridges.

This limit state includes live loads, LL, water loads, WA, in the presence of scour, SC. The probability that the maximum scour depth is present at the same time that maximum live loads are on the bridge is significant. Therefore, 1.80 times the maximum calculated scour depth should be used in combination with the maximum factored live load.

Section 3 -Loads and Load Factors (SI)

SPECIFICATIONS

- EXTREME EVENT IV

Load combination relating to wind loads in the presence of scour.

- EXTREME EVENT V

Load combination relating to ice load, collision by vessels or vehicles in the presence of scour.

- EXTREME EVENT VI

Load combination relating to earthquakes with scour.

COMMENTARY

This limit state includes water loads, WA, and wind loads on structures, WS, in the presence of scour, SC. To account for the probability of a major windstorm occurring in the presence of the maximum scour , 70% of the calculated scour depth should be used in combination with wind loads.

This limit state includes water loads, WA, in the presence of scour, SC, in combination with either ice loads, collisions by vessels, or vehicles. The probability of a collision or maximum ice loads occurring in the presence the maximum scour depth is small. Therefore, only 60% of the calculated scour depth should be used in combination with either ice load or a collision.

This limit state includes water loads, WA and earthquakes in the presence of scour, SC. The probability of an earthquake occurring in the presence of the maximum scour depth is small. Therefore, consideration of using only 25% of design scour depth may be warranted. Similarly, consideration of basing water loads on mean discharges may be warranted.

The presence of scour may increase the natural period of the bridge system and lead to lower inertial forces. Hence, the worst case scenario from Extreme Events I and VI should be utilized.

The calibration of the scour combination factors for Extreme Events III through VI has been performed by Ghosn, Moses and Wang (2003) for bridge foundations set in river channels assuming independence between scour and other extreme events.

SPECIFICATIONS

- SERVICE I -

Load combination relating to the normal operational use of the bridge with 90 km/hr wind, and with all loads taken at their nominal values. Also related to deflection control in buried metal structures, tunnel liner plate and thermoplastic pipe and to control crack width in reinforced concrete structures.

- SERVICE II -

Load combination intended to control yielding of steel structures and slip of slip- critical connections due to vehicular live load.

- SERVICE III -

Load combination relating only to tension in prestressed concrete with the objective of crack control.

COMMENTARY

Compression in prestressed concrete components is investigated using this load combination. Service III is used to investigate tensile stresses in prestressed concrete components.

This load combination corresponds to the overload provision for steel structures in past editions of the AASHTO Specifications, and it is applicable only to steel structures. From the point of view of load level, this combination is approximately halfway between that used for Service I and Strength I Limit States.

The live load specified in these Specifications reflects, among other things, current exclusion weight limits mandated by various jurisdictions. Vehicles permitted under these limits have been in service for many years prior to 1993. There is no nationwide physical evidence that these vehicles have caused detrimental cracking in existing prestressed concrete components. The statistical significance of the 0.80 factor on live load is that the vent is expected to occur about once a year for bridges with two traffic lanes, less often for bridges with more than two traffic lanes, and about once a day for the bridges with a single traffic lane.

Section 3 -Loads and Load Factors (SI)

SPECIFICATIONS

- FATIGUE -

Fatigue and fracture load combination relating to repetitive gravitational vehicular live load and dynamic responses under a single design truck having the axle spacing specified in Article 3.6.1.4.1.

The load factors for various loads comprising a design load combination shall be taken as specified in Table 1. All relevant subsets of the load combinations shall be investigated. For each load combination, every load that is indicated to be taken into account and which is germane to the component being designed, including all significant effects due to distortion, shall be multiplied by the appropriate load factor and multiple presence factor specified in Article 3.6.1.1.2 if applicable. The products shall be summed as specified in Equation 1.3.2.1-1 and multiplied by the load modifiers specified in Article 1.3.2.
The factors shall be selected to produce the total extreme factored force effect. For each load combination, both positive and negative extremes shall be investigated.
In load combinations where one force effect decreases the effect of another, the minimum value shall be applied to the load reducing the force effect. For permanent force effects, the load factor which produces the more critical combination shall be selected from Table 2. Where the permanent load increases the stability or load-carrying capacity of a component or bridge, the minimum value of the load factor for that permanent load shall also be investigated.
The larger of the two values provided for load factors of TU, CR and SH shall be used for deformations and the smaller values for all other effects.
For the evaluation of overall stability of earth slopes with or without a foundation unit, only the maximum load factors shall be used.

COMMENTARY

The load factor, applied to a single design truck, reflects a load level which has been found to be representative of the truck population with respect to a large number of return cycles of stresses, and their cumulative effects in steel elements, components and connections.

This article reinforces the traditional method of selecting load combinations to obtain realistic extreme effects, and is intended to clarify the issue of the variability of permanent loads and their effects. As has always been the case, the Owner or Designer may determine that not all of the loads in a given load combination apply to the situation under investigation.

It is recognized herein that the actual magnitude of permanent loads may also be less than the nominal value. This becomes important where the permanent load reduces the effects of the transient ones.

It has been observed that the probability of permanent loads exceeding the nominal value is larger than the probability of being less.

In the application of permanent loads, force effects for each of the specified six load types should be computed separately. Assuming variation of one type of load by span, length or component within a bridge is not necessary. For example, when investigating uplift at a bearing in a continuous beam, it would not be appropriate to use the maximum load factor for permanent loads in spans which produce a negative reaction and the minimum load factor in the spans which produce a positive reaction. Consider the investigation of uplift. Uplift was treated as a separate load case in past editions of the AASHTO Standard Specifications, but now becomes a strength load combination. Where a permanent load produces uplift, that load would be multiplied by the maximum load factor, regardless of the span in which it is located. If another permanent load reduces the uplift, it would be multiplied by the minimum load factor, regardless of the span in which it is located. For example, at Strength I Limit State where the permanent load reaction is positive and live load can cause a negative reaction, the load combination would be 0.9DC + 0.65DW + 1.75(LL+IM). If both reactions were negative, the load combination would be 1.25DC + 1.50DW + 1.75(LL+IM). For each force effect, both extreme combinations may need to be investigated by applying either the high or the low load factor as appropriate. The algebraic sums of these products are the total force effects for which the bridge and its components should be designed.
Water load and friction are included in all strength load combinations at their respective nominal values.
For creep and shrinkage, the specified nominal values should be used. For friction, settlement and water loads, both minimum and maximum values need to be investigated to produce extreme load combinations.

Section 3 -Loads and Load Factors (SI)

Table 3.4.1-1 Load Combinations and Load Factors

Load Combination Limit State	DC DD DW EH EV ES	LL IM CE BR PL LS	WA	WS	WL	FR	TU CR SH	TG	SE	EQ	IC	CT	CV	SC
STRENGTH-I	γ_P	1.75	1.00	-	-	1.00	0.50/ 1.20	γ_{TG}	γ_{SE}	-	-	-	-	-
STRENGTH-II	γ_P	1.35	1.00	-	-	1.00	0.50/ 1.20	γ_{TG}	γ_{SE}	-	-	-	-	-
STRENGTH-III	γ_P	-	1.00	1.40	-	1.00	0.50/ 1.20	γ_{TG}	γ_{SE}	-	-	-	-	-
STRENGTH-IV EH, EV, ES, DW, DC ONLY	γ_P 1.5	-	1.00	-	-	1.00	0.50/ 1.20	–	–	-	-	-	-	-
STRENGTH-V	γ_P	1.00	1.00	1.20	1.20	1.00	0.50/ 1.20	γ_{TG}	γ_{SE}	-	-	-	-	-
EXTREME EVENT -I	γ_P	0.25	1.00	-	-	1.00	-	–	–	1.00	-	-	-	-
EXTREME EVENT-II	γ_P	0.25	1.00	0.30	-	1.00	-	–	–	-	1.00	1.00	1.00	-
EXTREME EVENT-III	γ_P	1.75	1.00	-	-	1.00	-	γ_{TG}	γ_{SE}	-	-	-	-	1.80
EXTREME EVENT-IV	γ_P	-	1.00	1.40	-	1.00	-	γ_{TG}	γ_{SE}	-	-	-	-	0.70
EXTREME EVENT-V	γ_P	-	1.00	-	-	1.00	-	-	-	-	1.00	1.00	1.00	0.60
EXTREME EVENT-VI	γ_P	-	1.00	-	-	1.00	-	-	-	1.00	-	-	-	0.25
SERVICE-I	1.00	1.00	1.00	0.30	0.30	1.00	1.00/ 1.20	γ_{TG}	γ_{SE}	-	-	-	-	-
SERVICE-II	1.00	1.30	1.00	-	-	1.00	1.00/ 1.20	-	-	-	-	-	-	-
SERVICE-III	1.00	0.80	1.00	-	-	1.00	1.00/ 1.20	γ_{TG}	γ_{SE}	-	-	-	-	-
FATIGUE – LL, IM & CE ONLY	-	0.75	-	-	-	-	-	-	-	-	-	-	-	-

Table 3.4.1-2 -Load Factors for Permanent Loads, γ_P

	Load Factor	
Type of Load	Maximum	Minimum
DC: Component and Attachments	1.25	0.90
DD: Downdrag	1.80	0.45
DW: Wearing Surface and Utilities	1.50	0.65
EH: Horizontal Earth Pressure • Active • At-rest	 1.50 1.35	 0.90 0.90
EV: Vertical Earth Pressure • Overall Stability • Retaining Structure • Rigid Buried Structure • Rigid Frames • Flexible Buried Structures other than Metal Box Culverts • Flexible Metal Box Culverts	 1.35 1.35 1.30 1.35 1.95 1.50	 N/A 1.00 0.90 0.90 0.90 0.90
ES: Earth Surcharge	1.50	0.75

Section 3 -Loads and Load Factors (SI)

SPECIFICATIONS

The load factor for temperature gradient, γ_{TG} and settlement, γ_{SE} shall be determined on a project-specific basis.

COMMENTARY

The load factor for temperature gradient should be determined based on:

- the type of structure, and
- the limit state being investigated

At this writing (1994), there is general agreement that in situ measurements of temperature gradients have yielded a realistic distribution of temperatures through the depth of some types of bridges, most notably concrete box girders. There is very little agreement on the significance of the effect of that distribution. It is generally acknowledged that cracking, yielding, creep and other non-linear responses diminish the effects. Therefore, load factors of less than 1.0 should be considered, and there is some basis for lower load factors at the strength and extreme event limit states than at the service limit state.

Similarly, open girder construction and multiple steel box girders have traditionally, but perhaps not necessarily correctly, been designed without consideration of temperature gradient, i.e., γ_{TG} = 0.0.

Past editions of the Standard Specifications used γ_{LL} = 0.0 in combination with earthquake effects. The possibility of partial live load, i.e., γ_{LL} < 1.0, with earthquake should be considered. Application of the Ferry-Borges Model for combining load events indicates that γ_{LL} = 0.25 is reasonable for a wide range of values of ADTT and a representative set of earthquake intensity and occurrence rate data.

3.4.2 Load Factors for Construction Loads

Load factors for the weight of the structure and appurtenances shall not be taken less than 1.25.

Unless otherwise specified by the Owner, the load factor for construction loads, for equipment and for dynamic effects shall not be less than 1.5. The load factor for wind shall not be less than 1.25. All other load factors shall be taken as 1.0.

C3.4.2

The load factors presented here should not relieve the contractor from the responsibility for safety and damage control during construction.

3.4.3 Load Factor for Jacking Forces

Unless otherwise specified by the Owner, the design forces for jacking in service shall not be less than 1.3 times the permanent load reaction at the bearing, adjacent to the point of jacking. Where the bridge will not be closed to traffic during the jacking operation, the jacking load shall also contain a live load reaction consistent with the maintenance of traffic plans, multiplied by the load factor for live load.

The design force for post-tensioning anchorage zones shall be taken as 1.2 times the maximum jacking force.

C3.4.3

The load factor of 1.2 applied to the maximum tendon jacking force results in a design load of about 96% of the nominal ultimate strength of the tendon. This number compares well with the maximum attainable jacking force, which is limited by anchor efficiency.

SPECIFICATIONS

COMMENTARY

C3.8.1.3

Based on practical experience, maximum live loads are not expected to be present on the bridge when the wind velocity exceeds 90 km/hr. Hence, the load factor corresponding to the treatment of wind on structures for the strength limit state is reduced to 1.20 in combination with a live load factor of 1.00. A 0.30 wind load factor is used for Service I limit state. Similarly, a 0.30 wind load factor is used for combinations involving vessel collisions

3.15 SCOUR: SC

The evaluation of scour depths at bridge piers and abutments shall follow the procedure outlined in Hydraulic Engineering Circular No. 18.

C.3.15

The HEC-18 manual (Richardson and Davis, 1995) presents the state of practice for the design, evaluation, and inspection of bridges for scour.

A scour safety factor equal to 2.00 should be used when checking foundation depths with the scour calculated from the HEC-18 model. The 2.00 factor ensures that bridges susceptible to scour have reliability levels similar to those of other bridges.

The scour safety factor is reduced to 1.80 for the combination of scour and live loads.

A scour safety factor equal to 0.60 is used for combinations involving vessel collisions.

A scour safety factor equal to 0.70 is used for combinations involving scour and wind loads.

A scour safety factor equal to 0.25 is used for combinations involving scour and earthquakes. Because the presence of scour may result in the reduction of bridge stiffness and thus a reduction in the inertial forces, it is critical that bridge safety be checked for earthquake effects with and without the presence of scour.

Section 3 -Loads and Load Factors (SI)

REFERENCES

Nowak A.S. (1999), NCHRP Report 368: Calibration of LRFD Bridge Design Code, NCHRP 12-33, Transportation Research Board, Washington, DC.

Ghosn, M., Moses, F. & Wang, J. (2003), NCHRP Report 489: Design of Highway Bridges for Extreme Events, NCHRP Project 12-48, Transportation Research Board of the National Academies, Washington, DC.

Ghosn, M. and Moses, F. (1998), NCHRP Report 406: Redundancy in Highway Bridge Superstructures, NCHRP Project 12-36(2), Transportation Research Board of the National Academies, Washington DC.

Liu, D., Ghosn, M., Moses, F., and Neuenhoffer, A. (2001), NCHRP 458: Redundancy in Highway Bridge Substructures, NCHRP Project 12-47, Transportation Research Board of the National Academies, Washington DC.

Richardson, E.V., and Davis, E.R. (1995), Evaluating Scour at Bridges, HEC-18, Federal Highway Administration, FHWA-IP-90-017, Washington, DC.

SPECIFICATIONS

2.6.4.4.2 Bridge Scour

As required by Article 3.7.5, scour at bridge foundations is investigated for two conditions:

- The design flood for scour: The streambed material in the scour prism above the factored total scour line shall be assumed to have been removed for design conditions. The design flood storm surge tide, or mixed population flood shall be the more severe of the 100-year event or an overtopping flood of lesser recurrence interval. Appropriate load combination and scour factors are provided in Table 3.4.1-1 under Extreme Events III, IV, V and VI.
- The check flood for scour: The stability of bridge foundation shall be investigated for scour conditions resulting from a designated flood storm surge tide, or mixed population flood equal to or exceeding the design flood but, not to exceed the 500-year event or an overtopping flood of lesser recurrence interval. A scour factor of 2.0 is specified for checking foundation stability under this condition.

If the site conditions, due to ice or debris jams, and low tailwater conditions near stream confluences dictate the use of a more severe flood event for either the design or check flood for scour, the Engineer may use such flood event.

Spread footings on soil or erodible rock shall be located so that the bottom of footing is below the factored scour depths determined for the check flood for scour. Spread footings on scour-resistant rock shall be designed and constructed to maintain the integrity of the supporting rock.

COMMENTARY

C2.6.4.4.2

A majority of bridges that have failed in the Unite States and elsewhere have failed due to scour.

The added cost of making a bridge less vulnerable to damage from scour is small in comparison to the to the cost of a bridge failure.

The design flood for scour shall be determined on the basis of the Engineer's judgment of the hydrologic and hydraulic flow conditions at the site. The recommended procedure is to evaluate scour due to the specified flood flows and to design the foundation for the event expected to cause the deepest factored total scour.

The recommended procedure for determining the factored total scour depth at bridge foundations is as follows:

- estimate the long-term channel profile aggradation or degradation over the service life of the bridge,
- estimate the long-term channel plan form change over the service life of the bridge,
- as a design check, adjust the existing channel and flood plain cross-sections upstream and downstream of bridge as necessary to reflect anticipated changes in the channel profile and plan form,
- determine the combination of existing or likely future conditions and flood events that might be expected to result in the deepest factored scour for design conditions,
- determine water surface profiles for a stream reach that extends both upstream and downstream of the

Section 2 -General Design and Location Features (SI)

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Deep foundations with footings shall be designed to place the top of the footing below the estimated factored contraction scour depth where practical to minimize obstruction to flood flows and resulting local scour. Even lower elevations should be considered for pile supported footings where the piles could be damaged by erosion and corrosion from exposure to stream currents. Where conditions dictate a need to construct the top of a footing to an elevation above the streambed, attention shall be given to the scour potential of the design.

When tendering or other pier protection systems are used, their effect on pier scour and collection of debris shall be taken into consideration in the design.

The stability of abutments in areas of turbulent flow shall be thoroughly investigated and exposed embankment slopes should be protected with appropriate scour countermeasures.

COMMENTARY

bridge site for the various combinations of conditions and events under consideration,

- determine the magnitude of the factored contraction scour and local scour at piers and abutments,
- evaluate the results of the scour analysis, taking into account the variables in the methods used, the available information on the behavior of the watercourse, and the performance of existing structures during past floods. Also consider present and anticipated future flow patterns in the channel and its flood plain. Visualize the effect of the bridge on these flow patterns and the effect of the flow on the bridge. Modify the bridge design where necessary to satisfy concerns raised by the scour analysis and the evaluation of the channel plan form.

Foundation designs should be based on the factored total scour depths estimated by the above procedure, taking into account appropriate geotechnical safety factors and load combination factors. Where necessary, bridge modifications may include:

- relocation or redesign of piers or abutments to avoid areas of deep scour or overlapping scour holes from adjacent foundation elements,
- addition of guide banks, dikes or other river training works to provide for smoother flow transitions or to control lateral movement of the channel,
- enlargement of the waterway area, or
- relocation of the crossing to avoid an undesirable location.

Foundations should be designed to withstand the conditions of scour for the design flood and the check flood. In general, this will result in deep foundations. The design of the foundations of existing bridges that are being rehabilitated should consider underpinning if scour indicates the need. Riprap and other scour countermeasures may be appropriate if underpinning is not cost effective.

Available technology has not developed sufficiently to provide reliable scour estimates for some conditions, such as bridge abutments, located in areas of turbulence due to converging or diverging flows.

SPECIFICATIONS

3.7.5 Change in Foundations Due to Limit State for Scour

The provisions of Article 2.6.4.4 shall apply.

The consequences of changes in foundation conditions of loaded structures resulting from the design flood for scour shall be considered using the factored scour depth and load combination factors provided in Table 3.4.1-1 for service limit states and extreme event limit states III, IV, V and VI.

Foundation instability due to factored scour depths resulting from the check flood for bridge scour and from hurricanes shall be considered using a factored scour depth. For the check of foundation stability a factor of 2.0 is specified.

COMMENTARY

C3.7.5

Statistically speaking, scour is the most common reason for the failure of highway bridges in the United States.

Provisions concerning the effects of scour are given in Section 2. Scour per se is not a force effect, but by changing the conditions of the substructure it may significantly alter the consequences of force effects acting on structures.