



Design Criteria and Exposure Zones

IBC Workshop: W-8 Service Life Design

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AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS



Presentation Overview



- This part of the worked example covers:
 - Overview of the bridge considered in this design example;
 - Overview of design criteria; and
 - Definition of exposure zones.

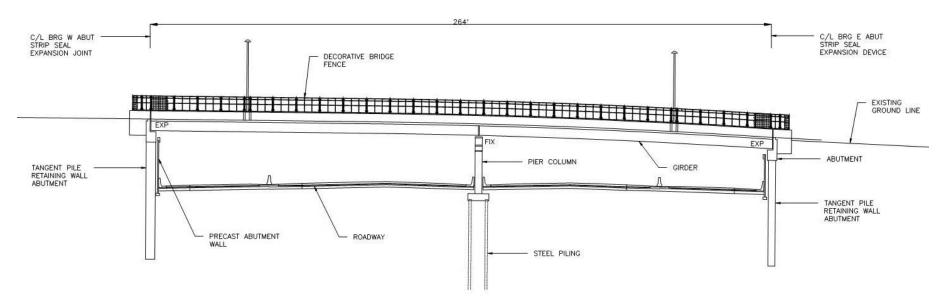
Location of the Bridge



- New York City.
- Highway under the bridge.
- Urban environment with periods of snow and freezethaw cycles.
- Annual mean temperature of 11.5°C (52.7°F).
- Heavy use of de-icing salts.
- Some sulfate present in soil: 0.14% by mass of water soluble sulfate was measured.

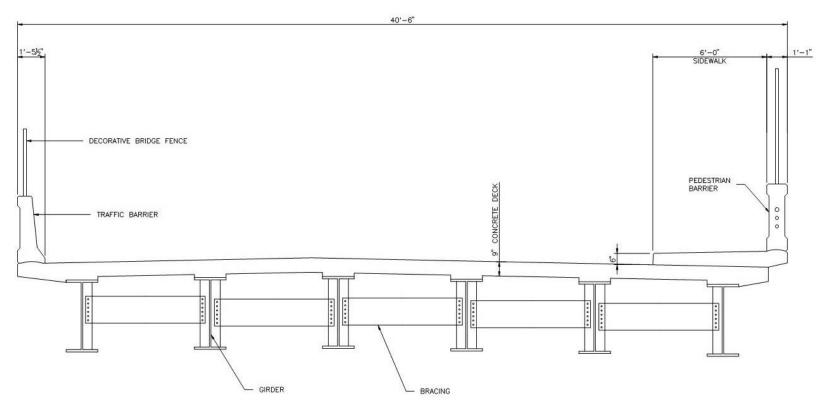
Arrangement of the Bridge

- General bridge characteristics:
 - 264 ft. steel girder bridge with two spans (139 ft. and 125 ft.).
 - Over the abutments, the girders are supported on elastomeric bearings and at the piers, the girders are supported on fixed bearings.
 - Deck and girders are continuous over the pier.
 - Uncoated reinforcement (black steel) used everywhere.



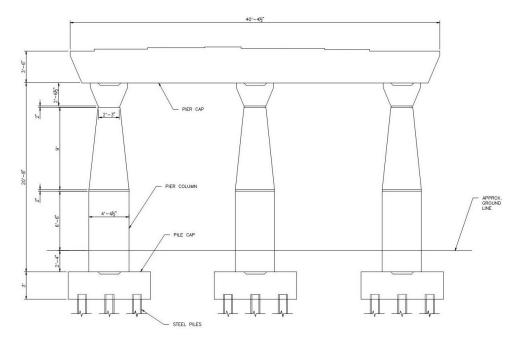
Bridge Superstructure

- General bridge superstructure characteristics:
 - Roadway is 30 ft. wide with two traffic lanes and shoulders, and a 6 ft. sidewalk.
 - Composite cast-in-place, high performance concrete deck on steel girders.
 - Deck is 9 in. thick with $2\frac{3}{4}$ " in. top cover and no wearing surface.



Bridge Substructure

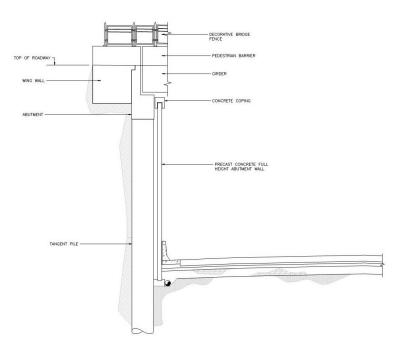
- General bridge substructure characteristics:
 - The central pier has three columns each supported by a pile cap and steel piles driven into bedrock:



- Uncoated reinforcement (black steel) used everywhere.
- No mass concrete.

Bridge Substructure

- General bridge substructure characteristics:
 - Abutments are supported by a reinforced concrete tangent pile wall:



- Full height precast abutment wall in front of the abutments protect them.
- Expansion joints are located between abutments and concrete deck.

Service Life Requirements

- Service life requirements:
 - Service life is defined as the period without major repairs or maintenance.
 Normal routine maintenance is expected.
 - Non-replaceable components must meet a minimum service life of 75 years.
 - Replaceable components must meet a minimum service life as below:

Non-Replaceable Components	Minimum Service Life (years)
Foundations, abutments, piers, structural steel, and deck	75
Replaceable Components	Minimum Service Life (years)
Bridge bearings	50
Expansion joints	30
Painting	25
Barriers	50

Service Life Requirements

• *fib* Bulletin 34 – Model Code for Service Life Design

design service life t _{SL} [years]	Examples
10	Temporary structures (structures or parts of structures that can be dismantled with a view to being re-used should not be considered as temporary)
10 - 25	Replaceable structural parts, e. g. gantry girders, bearings
15 - 30	Agricultural and similar structures
50	Building structures and other common structures
100	Monumental buildings structures, bridges, and other civil engineering structures

Table B1-1: Indicative values for the design service life t_{SL}

Service Life Design Procedure

- Recommended service life design procedure:
 - 1. Define exposure zones for all bridge components;
 - 2. Define deterioration mechanisms for each exposure zone;
 - 3. Define mitigation methods for deterioration mechanisms for concrete components; and
 - 4. Define mitigation methods for deterioration mechanisms for steel components.

Defined Exposure Conditions

Buried:

Zone permanently buried in soil. Abutment and tangent pile surfaces exposed to soil, pile cap, steel piles.

Atmospheric:

Zone not exposed to soil or de-icing salts. Bottom surface of deck, wing wall surfaces and tangent pile surfaces exposed to atmospheric air.

Indirect de-icing salts:

Zone subject to runoff water or spray containing de-icing salts, typically areas under and within 10 ft. of expansion joints or within 6 ft. to 20 ft. vertically of a roadway. Girder, bracing, pier column, pier cap, abutment wall.

Direct de-icing salts:

Zone directly exposed to the use of de-icing salts. Top surface of deck, traffic barrier, pedestrian barrier, piers directly next to roadway up to 6 ft. vertically of the roadway, fencing.

Defined Exposure Conditions

- American Concrete Institute ACI 318-2014 Building Code Requirements for Structural Concrete
 - Chapter 19 Concrete Design and Durability Requirements
 - Table 19.3.1.1 Exposure categories and classes

Table 19.3.1.1—Exposure categories and classes

Category	Class	Condition					
	F0	Concrete not exposed to freezing-and- thawing cycles					
Eroozing and	F1	Concrete exposed to freezing-and-thawing cycles with limited exposure to water					
Freezing and thawing (F)	F2	Concrete exposed to freezing-and-thawing cycles with frequent exposure to water					
	F3	Concrete exposed to freezing-and-thawing cycles with frequent exposure to water and exposure to deicing chemicals					

Table 19.3.1.1—Exposure categories and classes

Category	Class	Condition				
		Water-soluble sul- fate (SO ₄ ^{2–}) in soil, percent by mass ^[1]	Dissolved sulfate (SO ₄ ^{2–}) in water, ppm ^[2]			
	S0	${\rm SO_4}^{2-} < 0.10$	$SO_4^{2-} < 150$			
Sulfate (S)	S1	$0.10 \le \mathrm{SO_4}^{2-} < 0.20$	$150 \le \mathrm{SO_4}^{2-} < 1500$ or seawater			
	S2	$0.20 \le {\rm SO_4}^{2-} \le 2.00$	$1500 \le \mathrm{SO_4}^{2-} \le 10,000$			
	S3	${\rm SO_4}^{2-} > 2.00$	SO4 ²⁻ >10,000			

Table 19.3.1.1—Exposure categories and classes

Category	Class	Condition				
In contact with water (W)	W0	Concrete dry in service Concrete in contact with water and low permeability is not required				
	W1	Concrete in contact with water and low permeability is required				
	C0	Concrete dry or protected from moisture				
Corrosion protection of reinforcement (C)	C1	Concrete exposed to moisture but not to an external source of chlorides				
	C2	Concrete exposed to moisture and an external source of chlorides from deicing chemicals, salt, brackish water, seawater, or spray from these sources				

Defined Exposure Conditions

- European Standard EN 206:2013 Concrete Specification, performance, production, and conformity
 - 4.1 Exposure classes related to environmental actions
 - Table 1 Exposure Classes
 - Table 2 Limiting values for exposure classes for chemical attack from natural soil and groundwater

EN 206:2013 Exposure Classes

Table 1 – Exposure classes

Class designation	Description of the environment	Informative examples where exposure classes may occur							
3 Corrosion induced by chlorides other than from sea water									
containing chl	Where concrete containing reinforcement or other embedded metal is subject to contact with water containing chlorides, including de-icing salts, from sources other than from sea water, the exposure shall be classified as follows:								
XD1	Moderate humidity	Concrete surfaces exposed to airborne chlorides							
XD2 Wet, rarely dry		Swimming pools; Concrete exposed to industrial waters containing chlorides							
XD3 Cyclic wet and dry		Parts of bridges exposed to spray containing chlorides. Pavements, Car park slabs							
6 Chemica	l attack								
Where concre classified as for	te is exposed to chemical attack from natural so pllows:	ils and ground water, the exposure shall be							
XA1	Slightly aggressive chemical environment	Concrete exposed to natural soil and ground water according to Table 2							
XA2	Moderately aggressive chemical environment	Concrete exposed to natural soil and ground water according to Table 2							
XA3	Highly aggressive chemical environment	Concrete exposed to natural soil and ground water according to Table 2							

EN 206:2013 Exposure Classes

Table 2 — Limiting values for exposure classes for chemical attack from natural soil and ground water

Chemical characteristic	Reference test method	XA1	XA2	ХАЗ				
Ground water								
SO_4^{2-} mg/l	EN 196-2	\geq 200 and \leq 600	>600 and $\leq 3~000$	$>3~000$ and $\leq 6~000$				
рН	ISO 4316	\leq 6,5 and \geq 5,5	< 5,5 and ≥ 4,5	$< 4,5 \text{ and } \ge 4,0$				
CO ₂ mg/l aggressive	EN 13577	\geq 15 and \leq 40	$>$ 40 and \leq 100	> 100 up to saturation				
NH ₄ ⁺ mg/l	ISO 7150-1	\geq 15 and \leq 30	$>$ 30 and \leq 60	$> 60 \text{ and} \le 100$				
Mg ²⁺ mg/l	EN ISO 7980	≥ 300 and $\leq 1~000$	$00 \text{ and } \le 1\ 000$ > 1 000 and $\le 3\ 000$ > $3\ 000$					
		Soil						
SO ₄ ^{2–} mg/kg ^a total	EN 196-2 ^b	≥ 2 000 and ≤ 3 000 ^c	> 3 000 ^c and > 12 000 and ≤ 12 000 ≤ 24 000					
Acidity according to Baumann Gully ml/kg	prEN 16502	> 200	Not encountered in practice					

Defined Exposure Conditions

- International Standard ISO 12944 Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 2: Classifications of environments
 - 5 Classification of environments
 - Table 1 Atmospheric-corrosivity categories and examples of typical environments
 - Table 2 Categories for Soil and Water

ISO 12944 – Part 2 Atmospheric Exposures

Table 1 — Atmospheric-corrosivity categories and examples of typical environments

		ss per unit sur (after first year		Examples of typical environments in a temperate climate (informative only)		
Corrosivity	Low-carbo	on steel	Zi	nc	Exterior	Interior
category	Mass loss	Thickness loss	Mass loss	Thickness loss		
	g/m^2	μm	g/m^2	μm		
C3 medium	> 200 to 400	> 25 to 50	> 5 to 15	> 0,7 to 2,1	Urban and industrial atmospheres, moderate sulfur dioxide pollution. Coastal areas with low salinity.	Production rooms with high humidity and some air pollution, e.g. food-processing plants, laundries, breweries, dairies.
C4 high	> 400 to 650	> 50 to 80	> 15 to 30	> 2,1 to 4,2	Industrial areas and coastal areas with moderate salinity.	Chemical plants, swimming pools, coastal ship- and boatyards.
C5-M very high (marine)	> 650 to 1 500	> 80 to 200	> 30 to 60	> 4,2 to 8,4	Coastal and offshore areas with high salinity	Buildings or areas with almost permanent condensation and with high pollution.

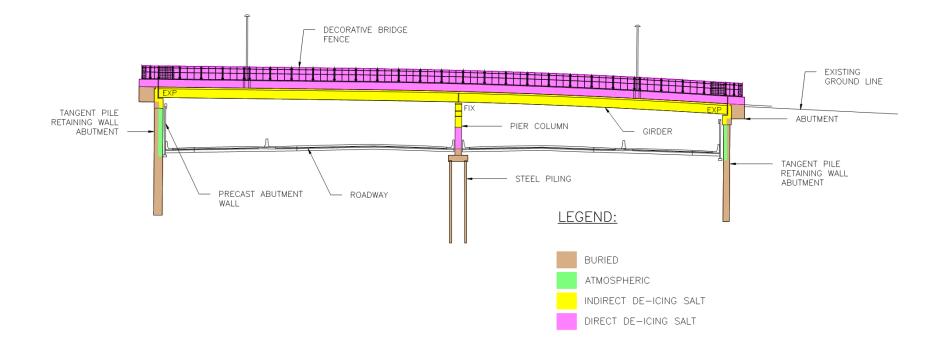
ISO 12944 – Part 2 Water and Soil Exposures



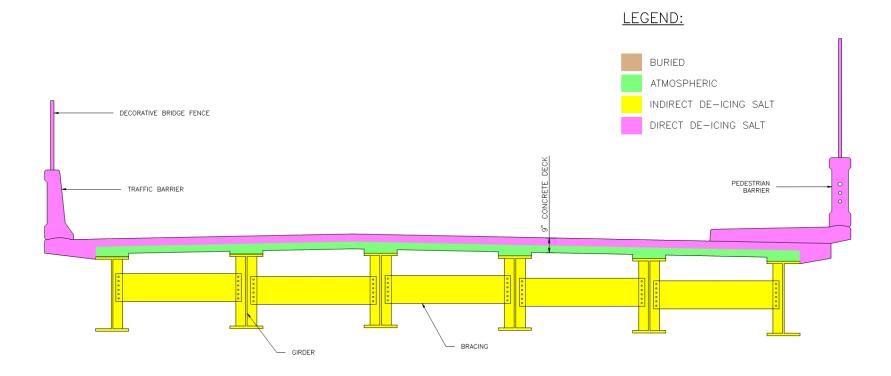
Table 2 — Categories for water and soil

Category	Environment	Examples of environments and structures
Im1	Fresh water	River installations, hydro-electric power plants
		Harbour areas with structures like sluice gates, locks, jetties; offshore structures
Im3	Soil	Buried tanks, steel piles, steel pipes

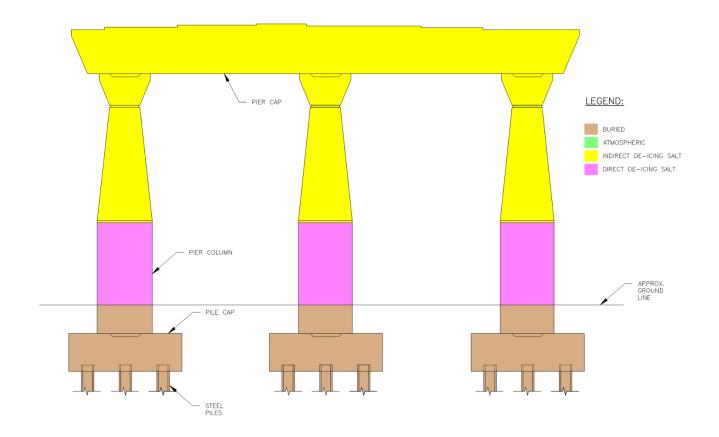
• Exposure zones for longitudinal section of the Bridge:



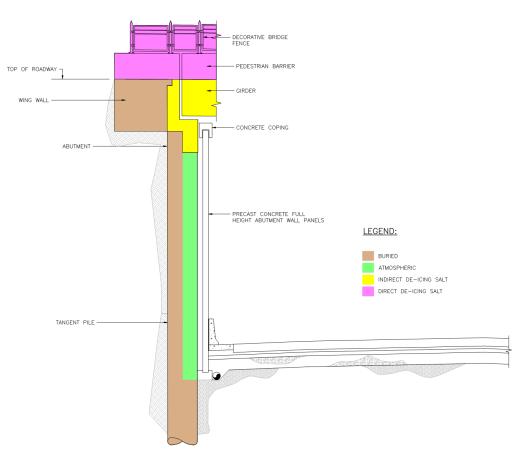
• Exposure zones for superstructure:



• Exposure zones for substructure:



• Exposure zones for abutments:



Collecting Environmental Data

- Climate/Weather
 - Temperature
 - Precipitation (Rain and/or Snow)
 - Freeze-Thaw Cycles
 - Relative Humidity
- Surface Chloride Concentration from De-Icing
 - Historical Data
 - Chloride Profiles from Existing/Nearby Structures

Search Tool »

https://www.ncdc.noaa.gov/cdo-web/





Q Climate Information Customer Support Search Home Data Access Contact About Home > Climate Data Online 🔲 Datasets 📕 Search Tool 📕 Mapping Tool 📕 Data Tools 🔯 Help Climate Data Online Climate Data Online (CDO) provides free access to NCDC's archive of global historical weather and climate data in addition to station history information. These data include quality controlled daily, monthly, seasonal, and yearly measurements of temperature, precipitation, wind, and degree days as well as radar data and 30-year Climate Normals. Customers can also order most of these data as certified hard copies for legal use. **Browse Datasets** Certify Orders **Check Status** Find Help Get orders certified for legal use Browse documentation, Check the status of an order Find answers to questions about (requires payment) samples, and links that has been placed data and ordering Select **DISCOVER DATA BY** DATA TOOLS SEARCH TOOL MAPPING TOOL Search for and access past weather and Find and view past weather and climate Access past weather and climate data climate data by station name or data by station name or identifier, ZIP using a collection of specialized tools. identifier, ZIP code, city, county, state, or code, city, county, state, or country.

Data Tools »

Mapping Tool »



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Climate Information

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Climate Data Online Data Tools

Data Access

The following tools allow alternative methods of accessing the data that is available within Climate Data Online. Some of these are visualization only, while others allow different options such as downloads. Each tool is specialized to a specific dataset or use case. Choose one of the data tools below for access.

Search Across Multiple Datasets

The following tools access data from multiple datasets at once for a unified look at the data available across a geographic region. Data may not be in a standardized format since the datasets available may not have similar formats.



Locate weather observing stations using a variety of parameters such as address, ZIP code, date, and data type with filters by observation type



Select a Location

Order data by weather observing stations or by geographic locations using a simplified drill-down interface with data from U.S. and other countries





Home	Climate Information	Data Access	Customer Support	Contact	About	Search	Q
Home > (Climate Data Online > Data To	ools > Find a Station	4		Datasets 📘 Se	arch Tool 📕 Mapping Tool	📕 Data Tools 🛛 🖉 Help

Data Tools: Find a Station

Retrieve weather records from observing stations by entering the desired location, data set, data range, and data category. Location can be specified as city, county, state, country, or ZIP code.

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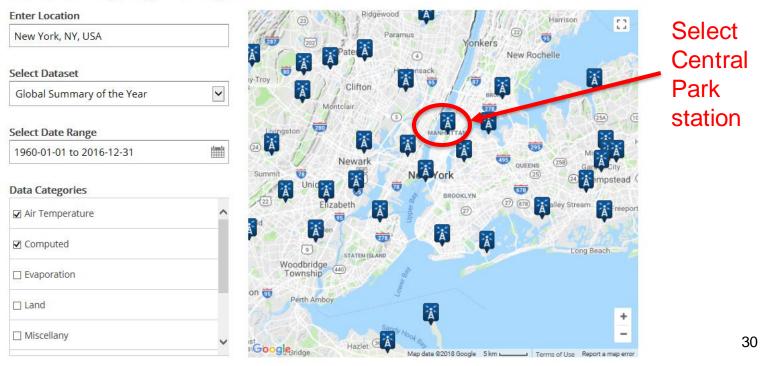




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Data Tools: Find a Station

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Cart: Global Summary of the Year

Step 1: Choose Options

Step 2: Review Order S

Step 3: Order Complete

Select Cart Options

Specify the desired formatting options for the data added in the cart. These options allow more refined date selection, selection of the processed format, and the option to remove items from the cart.

Select the Output Format

Choose one option below to choose a type of format for download. Formats are a standard PDF format. Other formats are CSV (Comma Separated Value) and Text format, both of which can be opened with programs such as Microsoft Excel or OpenOffice Calc. Some formats have additional options which can be selected on the next page.

> Global Summary of The Year PDF DOC Certification Option (Does not include all elements)

Include Documentation

Custom Global Summary of The Year CSV (Additional options available on next page)

Help

Have questions about the data? Need some assistance? Use the links below to quickly find the answers you need.

Climate Data Online help Check order status Request assistance

Need technical documentation or assistance with systems access?

View data samples & documentation NCDC Web Services CDO Web Services Documentation

NOAA Climate Data (pdf)

U.S. Department of Commerce National Oceanic & Atmospheric Administration National Environmental Satellite, Data, and Information Service Current Location: Elev: 140 ft. Lat: 40.7790° N Lon: -73.9693° W Global Summary of the Year 1960 - 1985 Generated on 05/25/2018 National Centers for Environmental Information 151 Patton Avenue Asheville, North Carolina 28801

Station: NY CITY CENTRAL PARK, NY US USW00094728

Date	Temp	perature (Fahrenheit)		Degree Days (Base 65 degrees)		Extremes				Number of Days			
Elem->	TAVG	TMAX	TMIN	HTDD	CLDD	EMXT		EMNT		DX90	DX32	DT32	DT00
Year	Annual Mean Temp	Mean Max Temp	Mean Min Temp	Heating Degree Days	Cooling Degree Days	Extreme Max Temp	Date of Occurrence	Extreme Min Temp	Date of Occurrence	Max Temp >= 90F	Max Temp <= 32F	Min Temp <= 32F	Min Temp <= 0F
1960	54.0	61.5	46.5	4898	978	91+	Aug-27	8	Dec-13	5	19	99	
1961	55.0	62.7	47.4	5110	1344	97	Jul-22	-2	Feb-02	29	22	74	
1962	53.4	61.5	45.3	4738	977	99	May-19	4+	Dec-31	18	22	79	
1963	53.5	61.8	45.2	5328	920	98+	Jul-27	-2	Feb-08	16	30	78	
1964	54.5	62.7	46.4	4859	1033	99+	Jul-01	9	Jan-14	23	13	75	
1965	54.2	62.0	46.3	5015	991	95	Jun-29	9	Jan-17	15	19	71	
1966	55.0	63.0	47.1	4818	1322	103	Jul-03	8+	Feb-20	35	19	77	
1967	52.9	60.6	45.3	5236	989	96	Jun-16	4	Feb-13	9	20	86	
1968	54.0	62.0	46.1	5246	1109	98	Jul-17	-1	Jan-09	17	26	87	
1969	54.8	62.1	47.4	4770	1199	97	May-29	11	Jan-28	16	17	90	
1970	54.2	61.7	46.8	5283	1269	94+	Sep-22	3	Jan-09	22	29	91	
1971	55.2	62.3	48.1	5057	1305	96	Jul-08	4	Jan-19	18	18	70	
1972	53.8	61.4	46.2	4743	1033	94+	Aug-24	5	Jan-16	15	19	78	
1973	56.0	63.8	48.3	4797	1259	98+	Aug-30	7	Feb-17	18	16	60	
1974	54.7	62.5	46.8	4594	1062	95+	Jul-14	6	Jan-18	17	19	80	
1975	54.9	62.3	47.5	4771	993	98	Aug-02	15	Jan-21	8	12	75	
1976	53.3	61.4	45.3	4660	1049	96	Apr-18	-1	Jan-23	15	29	92	
1977	54.3	61.6	47.0	5502	1234	104	Jul-21	-2	Jan-17	23	40	77	
1978	52.9	60.1	45.8	5427	992	95	Jul-23	10+	Feb-05	11	38	86	
1979	55.7	62.8	48.5	4826	1185	95+	Aug-10	0	Feb-18	18	25	63	
1980	54.9	62.6	47.3	4521	1405	102	Jul-21	-1	Dec-25	32	26	83	
1981	55.2	62.3	48.0	4953	1206	96	Jul-09	2	Jan-12	16	23	70	
1982	54.8	62.1	47.6	5074	1034	98	Jul-18	0+	Jan-18	11	21	74	
1983	56.0	63.2	48.7	4378	1402	99	Sep-11	4	Dec-25	36	18	57	
1984	55.4	62.4	48.5	4923	1118	96	Jun-09	8	Jan-21	10	21	60	
1985	55.5	62.9	48.1	4331	1131	95	Aug-15	-2	Jan-21	9	23	81	



U.S. Department of Commerce

National Oceanic & Atmospheric Administration

National Environmental Satellite, Data, and Information Service

Current Location: Elev: 140 ft. Lat: 40.7790° N Lon: -73.9693° W Station: NY CITY CENTRAL PARK, NY US USW00094728

Date	Temperature (Fahrenheit)								
Elem->	TAVG	TMAX	TMIN						
Year	Annual Mean Temp	Mean Max Temp	Mean Min Temp						
2012	57.3	64.3	50.3						
2013	55.3	62.3	48.4						
2014	54.4	61.6	47.2						
2015	56.7	64.1	49.2						
2016	57.2	64.6	49.8						

 Annual Snowfall

Frozen Precipitation (Inches)											
SNOW	EMSN		EMSD								
Snowfall	Extreme Max Snowfall	Date of Occurrence	Extreme Max Snow Depth	Date of Occurrence							
9.6	4.3+	Nov-07	4	Nov-08							
29.7	6.3	Feb-08	11	Feb-09							
50.0	11.0	Jan-21	18+	Feb-18							
49.1	7.5	Mar-05	19	Mar-06							
36.0	27.3	Jan-23	22	Jan-24							

 Freeze-Thaw Cycles (DT32 - DX32)

Number of Days										
DX90	DX32	DT32	DT00							
Max Temp >= 90F	Max Temp <= 32F	Min Temp <= 32F	Min Temp <= 0F							
19	5	38	0							
17	20	77	0							
8	29	82	0							
20	26	71	0							
22	12	58	1							

NOAA Climate Data (CSV)

• File converted to Excel for data manipulation

		#	Extreme Maximums (in)			Total Ar	nual (in)	Temperature (°F)					
	Rain	Snow	Snow-	Tmin	Tmax	Snowd	Snow-	Rain-	Rain-	Snow-			
	>0.1"	depth >1"	fall	≤32°F	$\geq 32^{\circ} F$	epth	fall	fall	fall	fall			
DATE	DP01	DSND	DSNW	DT32	DX32	EMSD	EMSN	EMXP	PRCP	SNOW	TAVG	TMAX	TMIN
1960	115	31	9	99	19	15	12.5	3.56	46.43	41.6	54	61.5	46.5
1961	119	43	9	74	22	24	11.4	2.1	39.36	43.8	55	62.7	47.4
1962	109	17	6	79	22	3	2.9	2.33	37.17	15	53.4	61.5	45.3
1963	115	25	9	78	30	6	6	2.96	34.31	23	53.5	61.8	45.2
1964	113	28	10	75	13	13	11.5	1.29	33.02	36.5	54.5	62.7	46.4
1965	103	21	8	71	19	6	6.3	1.35	26.12	21.3	54.2	62	46.3
1966	116	28	9	77	19	8	6.7	5.54	39.91	30.4	55	63	47.1
1967	126	28	13	86	20	13	12.5	2.15	49.14	51.2	52.9	60.6	45.3
1968	109	21	5	87	26	5	5.5	3.99	43.6	17.8	54	62	46.1
1969	120	34	9	90	17	15	14	3.32	48.54	30	54.8	62.1	47.4

Summary of Environmental Data

- Climate/Weather (Annual Mean Values)
 - Temperature $55.1^{\circ}F = 12.8^{\circ}C$ (Std. Dev. = $0.6^{\circ}C$)
 - Snowfall 27 inches (Std. Dev. = 14.3 inches)
 - Freeze-Thaw Cycles -53.6 (Std. Dev. = 9.3)
- Surface Chloride Concentration from De-Icing
 - Taken from Historical Data 4% mass of cementitious materials (Std. Dev. = 2%)

Questions?



Implementation Leads:

- Patricia Bush, AASHTO Program Manager for Engineering, pbush@aashto.org
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Resource: AASHTO's R19A Product Page

 http://shrp2.transportation.org/Pages/ServiceLifeDesignf orBridges.aspx