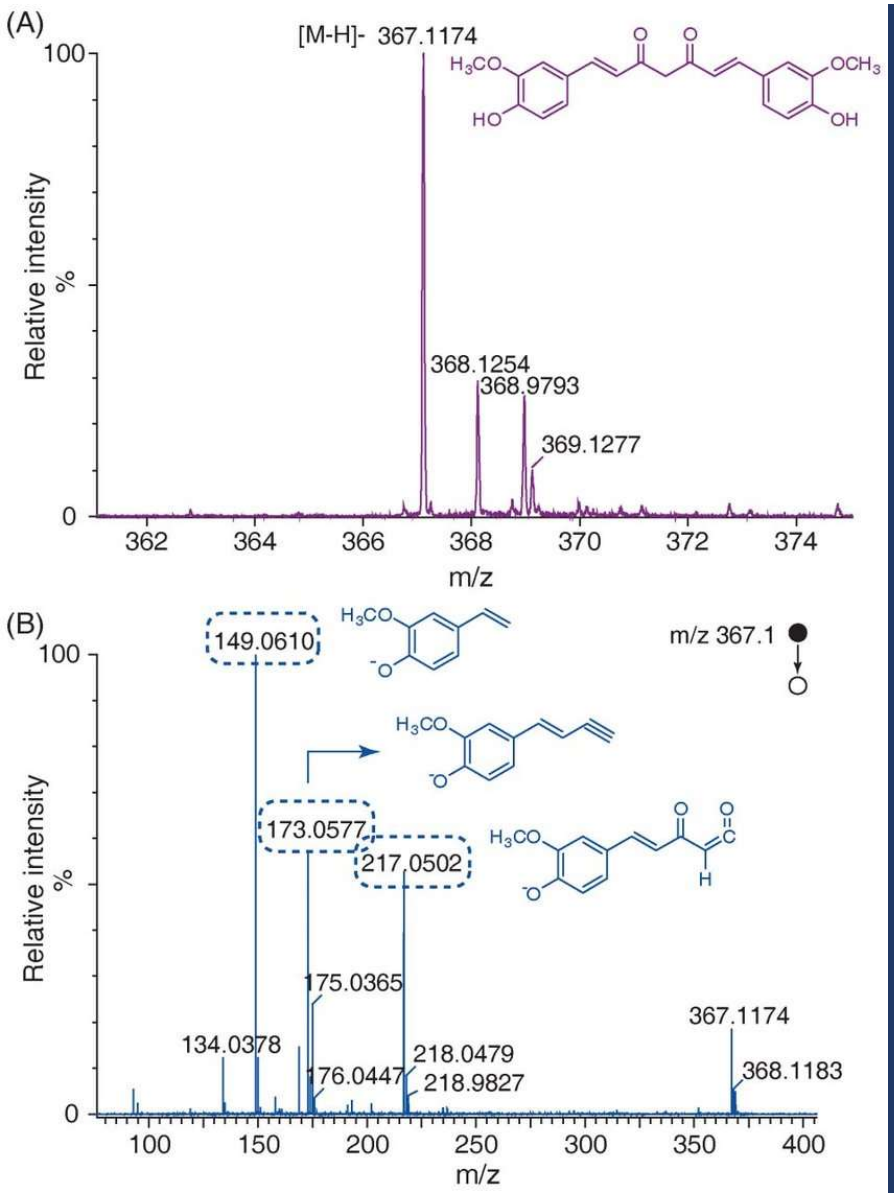
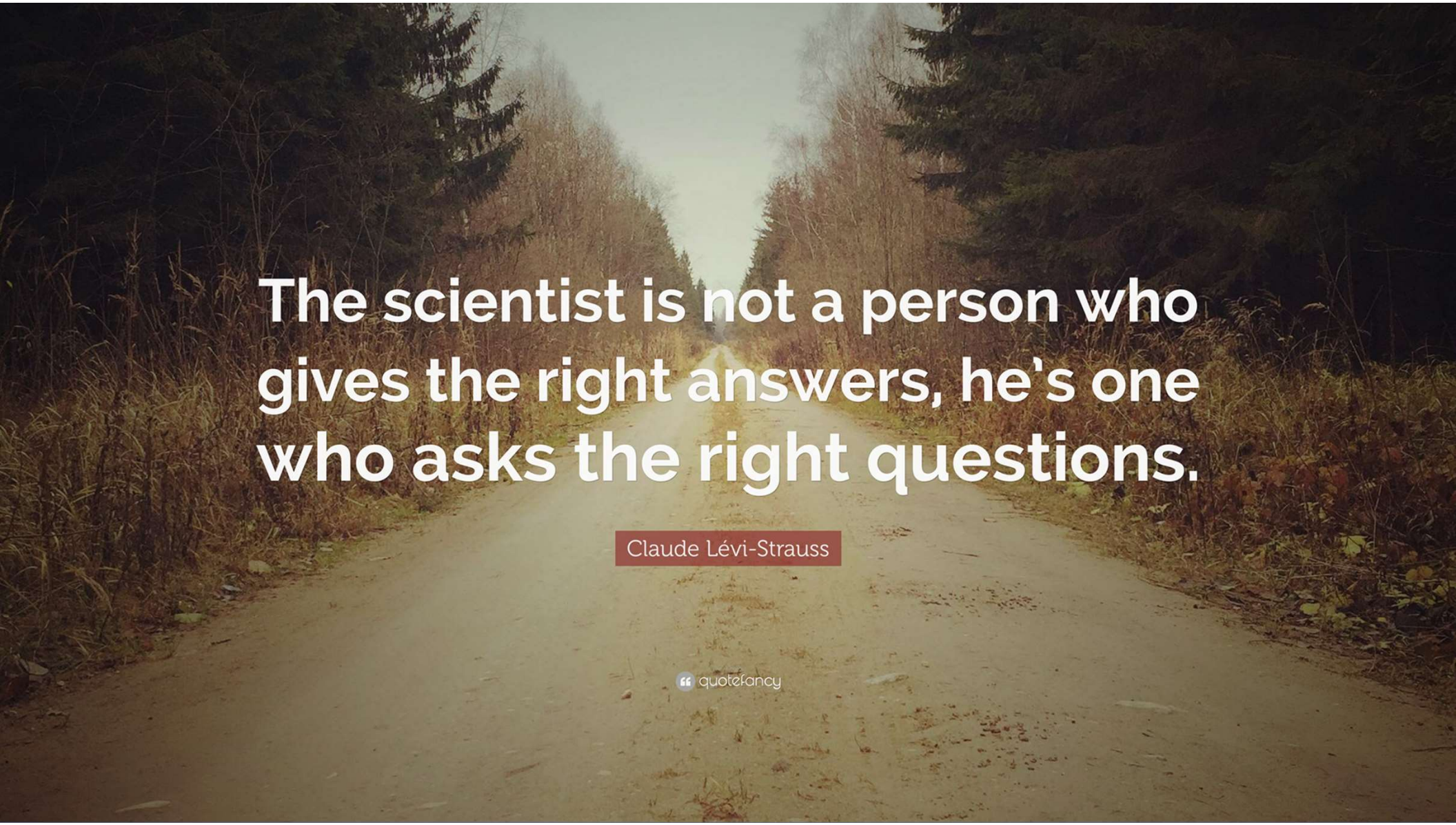
Durability 101

Prof. Norman R. Weiss FAIC, FAPT, FSA
Columbia University


(A)
[M-H]- 367.1174
100
0
Relative intensity
%
368.1254
368.9793
369.1277
362
364
366
368
370
372
374
m/z
(B)
149.0610
m/z 367.1
173.0577
217.0502
175.0365
134.0378
218.0479
176.0447
218.9827
367.1174
368.1183
100
150
200
250
300
350
400
m/z


The scientist is not a person who gives the right answers, he's one who asks the right questions.
Claude Lévi-Strauss
quotefancy


SPENCER THORLEY
LONDON & PARIS

characterized in the following table:

Materials associated with construction campaigns:

PERIOD	SUBSTRAT	MORTAR	ROUGH COAT	STUCCO	FINISH
1634-1640	Cut limestone	White	_	White	Smooth, shiny
1785-1792	Rubble-masonry	Red-orange	Red-orange	Buff	Smooth, shiny
	Cut limestone	Red-orange	Red-orange	Pink	Smooth, shiny
1792-1835	Tapia	Tapia	Red-orange (Tapia?)	Gray	Smooth, shiny

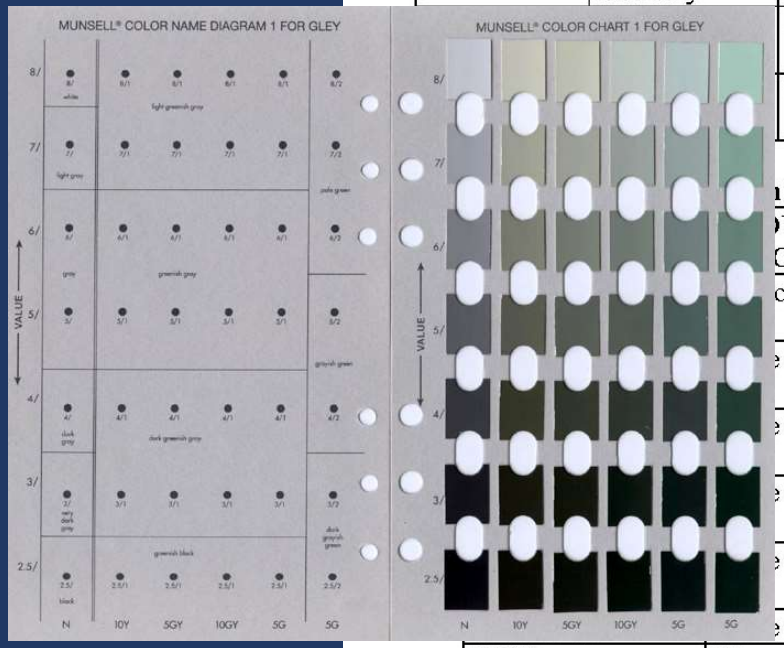
Materials associated with repair campaigns:

PERIOD	ROUGH COAT	REPAIR STUCCO	FINISH
1785-1792	Red-orange	Buff	Smooth, Shiny
	None	White with brick chips	None found
1800-1830	None	Pink with brick chips	Pink, smooth & shiny
ca. 1897	None	Tan/grey cementitious	Smooth, shiny
Unknown	None	Peach with shells	Rough texture, with aggregate
1927-1928	None	Tan cementitious	Smooth, not shiny
1947	None	Tan cementitious	Flat, not smooth
XX century (unknown)	None	Dark pink cementitious	Flat, not smooth
XX century (unknown)	None	Dark pink with brick chips	None found
Late XX century (up to 1995)	None	Cream	Rough texture with aggregate

characterized in the following table:

Materials associated with construction campaigns:

PERIOD	SUBSTRAT	MORTAR	ROUGH COAT	STUCCO	FINISH
1634-1640	Cut limestone	White	_	White	Smooth, shiny
1785-1792	Rubble-masonry	Red-orange	Red-orange	Buff	Smooth, shiny
		Red-orange	Red-orange	Pink	Smooth, shiny
		Tapia	Red-orange (Tapia?)	Gray	Smooth, shiny



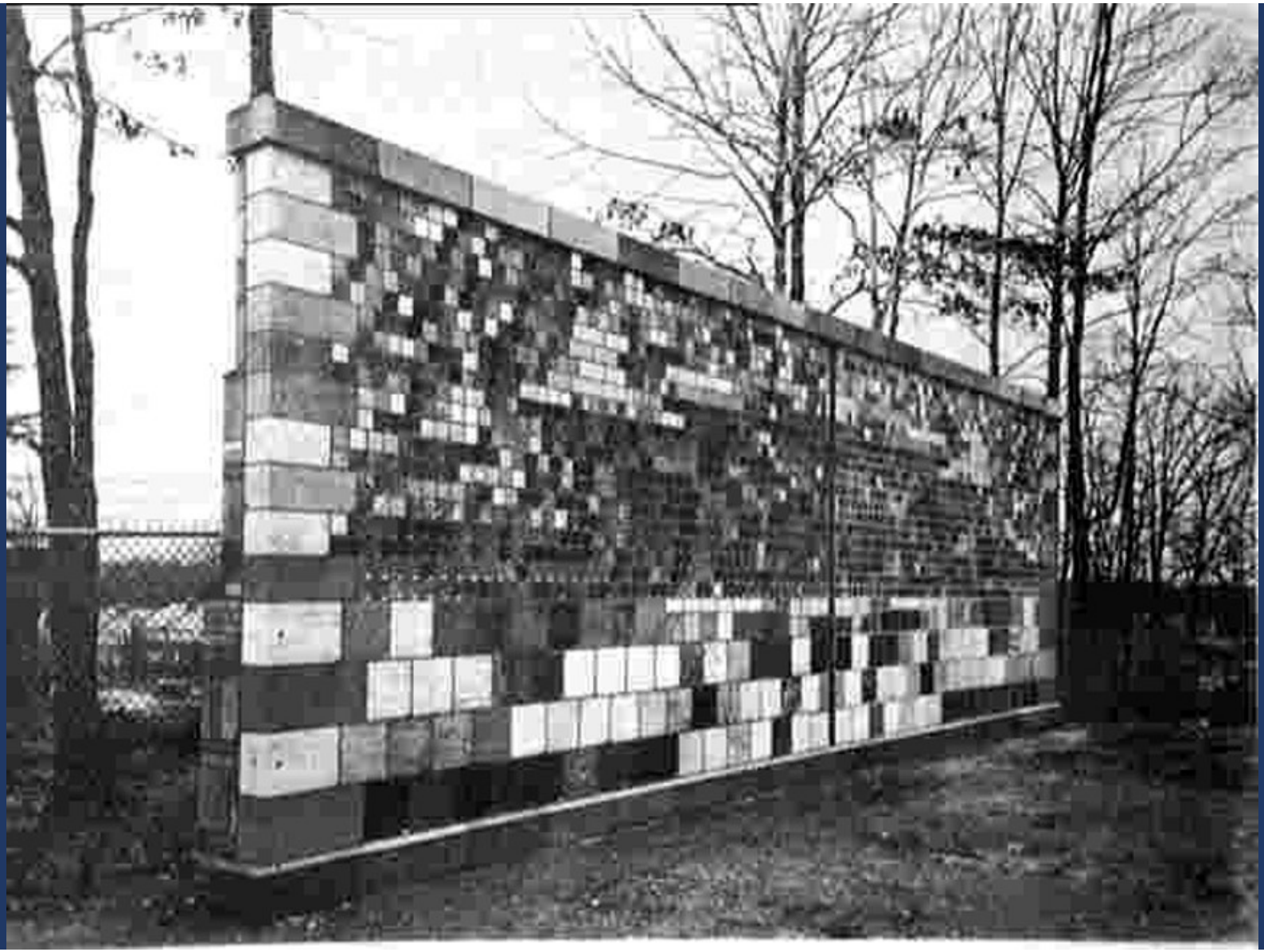
repair campaigns:

ROUGH COAT	REPAIR STUCCO	FINISH
orange	Buff	Smooth, Shiny
	White with brick chips	None found
	Pink with brick chips	Pink, smooth & shiny
	Tan/grey cementitious	Smooth, shiny
	Peach with shells	Rough texture, with aggregate
	Tan cementitious	Smooth, not shiny
None	Tan cementitious	Flat, not smooth
None	Dark pink cementitious	Flat, not smooth
None	Dark pink with brick chips	None found
None	Cream	Rough texture with aggregate

What is durability?

Durability is the consistency of performance. And performance is in-service behavior over time.

Durability **is the consistency of performance. And** ***performance*** **is in-service** ***behavior*** **over time.**



But durability can be…

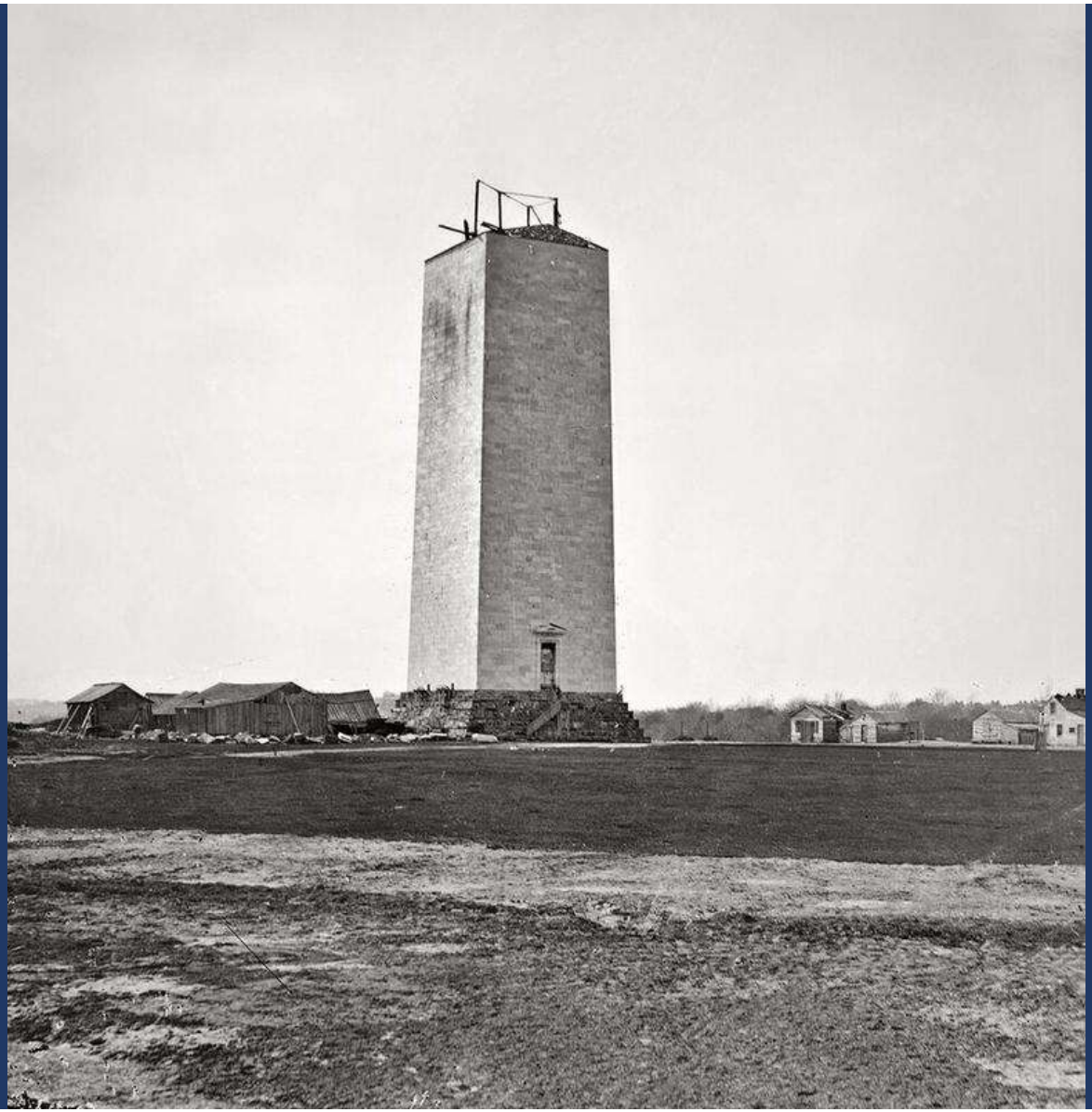
****structural durability**
****materials durability**
****aesthetic durability**

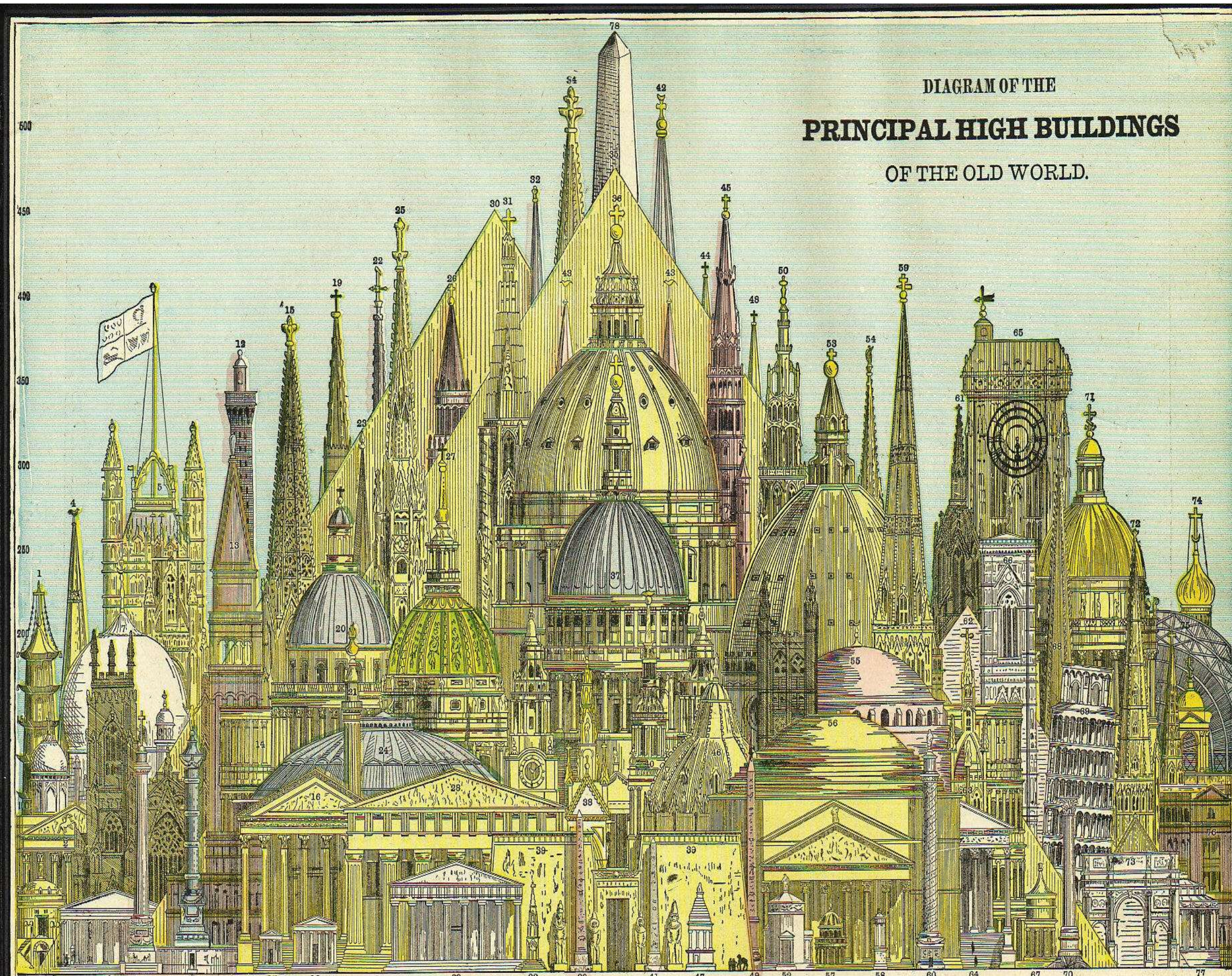
But durability can be…

****structural durability**

****materials durability**

****aesthetic durability**





	Feet High.
1. Porcelain Tower, Nankin, China	200
2. St. George's Hall, Liverpool	85
3. Tomb of Theodoric, Ravenna	50
4. Chichester Cathedral	271
5. Victoria Tower, Westminster	331
6. Boston Church, Lincolnshire	292
7. Taj Mahal, Agra	220
8. York Cathedral	198
9. Temple of Bacchus, Teos	50
10. Alexandrian Column, St. Petersb'g	154
11. Column of July, Paris	154
12. Torre Asinelli, Bologna	370
13. Bell Tower, St. Mark's, Venice	323
14. Coloseum, Rome	157
15. Friburg Cathedral	385
16. Temple of the Sun, Baalbec	120
17. Temple on the Ilissus, Athens	25
18. Erechtheium, Athens	35
19. Chartrea Cathedral	403
20. Church of Ste Genevieve, Paris	274
21. The Monument, London	202
22. Amiens Cathedral	383
23. Church of St. Theobald, Tharin	320
24. Royal Albert Hall, London	154
25. St. Stephen's Cathedral, Vienna	441
26. Torazzo of Cremona	396
27. Hotel des Invalides, Paris	310
28. Temple of the Giants, Agrigentum	116
29. Parthenon, Athens	66
30. Second Pyramid, Gheezeh	447
31. Rouen Cathedral	460
32. Strasburg Cathedral	468
33. Eleanor Cross, Waltham	50
34. Cologne Cathedral	510
35. Great Pyramid	460
36. St. Peter's, Rome	448
37. St. Paul's, London	360
38. Albert Memorial	180
39. { Obelisk, Luxor	75
{ Prophylon	70
40. Bow Church, London	235
41. Cleopatra's Needle	68
42. Old St. Paul's, London	508
43. Church of St. Mary, Lubeck	400
44. Abbey of St. Stephen, Caen	400
45. Church of St. Martin, Landshut	460
46. The Baptistry, Pisa	190
47. Tomb at Mylasa, Caria	50
48. Church of St. Peter, Hamburg	380
49. Obelisk in Piazza di San Giovanna in Laterano, Rome	153
50. Antwerp Cathedral	403
51. "Bell Harry" Tower, Canterbury	235
52. Tower of the Winds, Athens	45
53. The Cathedral, Florence	376
54. Hotel de Ville, Brussels	374
55. Mosque of St. Sophia, Constantinople	182
56. Pantheon, Rome	143
57. Chapel of St. Pietro Montorio, Rome	40
58. Choragic Monument of Lysicrates, Athens	34
59. Salisbury Cathedral	404
60. Trajan Column, Rome	134
61. Cathedral, Frankfort-on-Main	326
62. Pyramid of Mycirinus	218
63. Church of St. Nicholas, Newcastle-on-Tyne	201
64. Temple of Jupiter Stator, Rome	98
65. Mechlin Cathedral	319
66. Bell Tower, Florence	266
67. Tomb of Absolom, Jerusalem	54
68. Norwich Cathedral	309
69. Leaning Tower, Pisa	188
70. Pompey's Pillar, Alexandria	100
71. Church of St. Isaac, St. Petersburg	336
72. { Central Spire, Lichfield	252
{ Western Spire	192
73. Arch of Constantine, Rome	70
74. Tower of Ivan Veliki, Moscow	260
75. Central Transept, Crystal Palace	198
76. Science Schools, South Kensington	110
77. Temple of Vesta, Tivoli	55
78. Washington Monument	555

The Red Tint indicates BRICK; *the Stone Color*, STONE; *the Pink*, GRANITE; *the Purple*, BRONZE, COPPER *or* LEAD; *and the Yellow*, GOLD.

DIAGRAM OF THE

PRINCIPAL HIGH BUILDINGS

OF THE OLD WORLD.

Feet High.

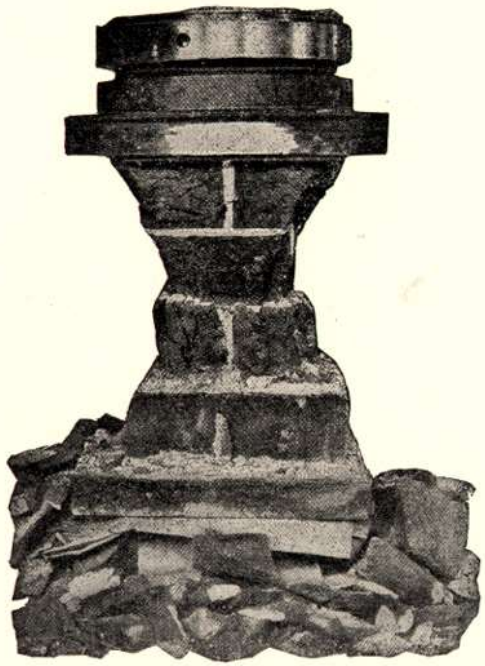
1. Porcelain Tower, Nankin, C
2. St. George's Hall, Liverpool
3. Tomb of Theodoric, Ravenn
4. Chichester Cathedral
5. Victoria Tower, Westminst
6. Boston Church, Lincolnshir
7. Taj Mahal, Agra
8. York Cathedral
9. Temple of Bacchus, Teos
10. Alexandrian Column, St. Petersb'g 154
11. Column of July, Paris 154
12. Torre Asinelli, Bologna 370
13. Bell Tower, St. Mark's, Venice 323
14. Coloseum, Rome 157
23. Church of St. Theobald, Paris 330
24. Royal Albert Hall, London 154
25. St. Stephen's Cathedral, Vienna 441
26. Torazzo of Cremona 396
27. Hotel des Invalides, Paris 310
28. Temple of the Giants, Agrigentum 116
37. St. Paul's, London 360
38. Albert Memorial 180
39. } Obelisk, Luxor 75
} Prophylon 70
40. Bow Church, London 235
41. Cleopatra's Needle 68
In Laterano, Rome 103
50. Antwerp Cathedral 403
51. "Bell Harry" Tower, Canterbury 235
52. Tower of the Winds, Athens 45
53. The Cathedral, Florence 376
54. Hotel de Ville, Brussels 374
61. Cathedral, Frankfort on Main 318
62. Pyramid of Mycerinus 203
63. Church of St. Nicholas, Newcastle-on-Tyne 201
64. Temple of Jupiter Stator, Rome 98
65. Mechlin Cathedral 319
74. Tower of Ivan Velikl, Moscow 360
75. Central Transept, Crystal Palace 198
76. Science Schools, South Kensington 110
77. Temple of Vesta, Tivoli 55
78. Washington Monument 555

The Red Tint indicates BRICK; *the Stone Color,* STONE; *the Pink,* GRANITE; *the Purple.* BRONZE. COPPER *or* LEAD; *and the Yellow,* GOLD.

SERIES IV. (*A*)

THE STRENGTH OF MORTAR IN COMPRESSION IN BRICK MASONRY.

All engineers realize that the strength of mortar is much less tested in cubes than in thin layers, but just what proportion they bear to one another is not very well known. The following experi-



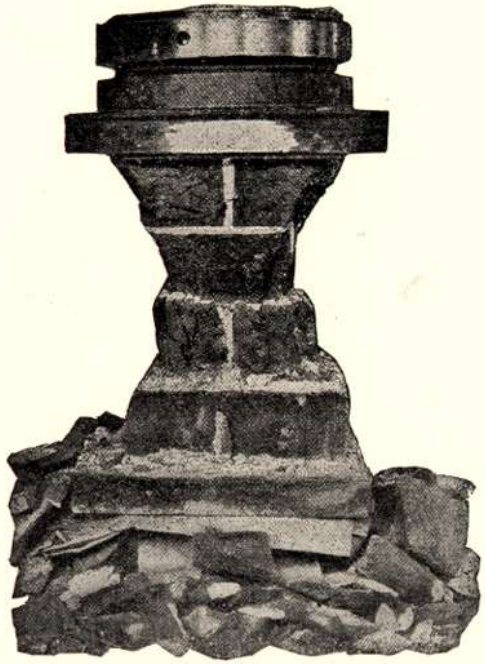
ments have been made with a view of obtaining this information, (See table VII.).

At the same time that these tests were made, mortar was also made into test pieces, and tested at the same age. We are thus enabled to form an idea of the relative strengths of mortar in thin joints and in cubes, and also to form an intelligent opinion of the comparative strengths of lime mortar, natural cement mortar, and Portland cement mortar. The mortars of the fourth, fifth, and sixth

SERIES IV. (*A*)

THE STRENGTH OF MORTAR IN COMPRESSION IN BRICK MASONRY.

All engineers realize that the strength of mortar is much less tested in cubes than in thin layers, but just what proportion they bear to one another is not very well known. The following experi-

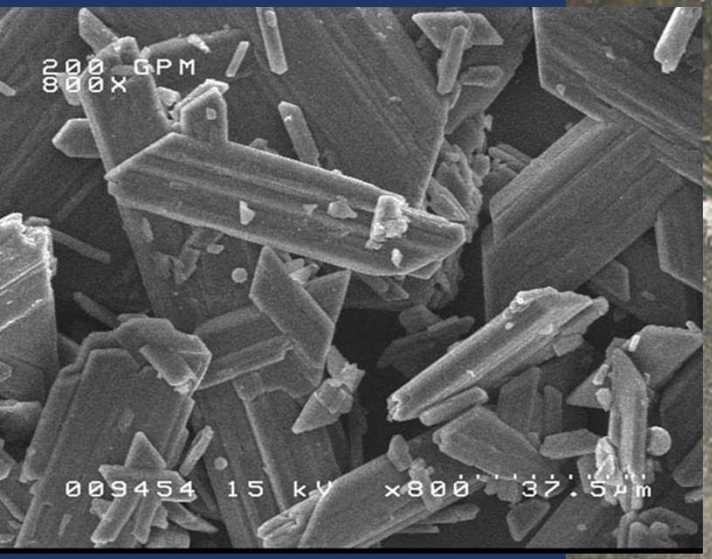


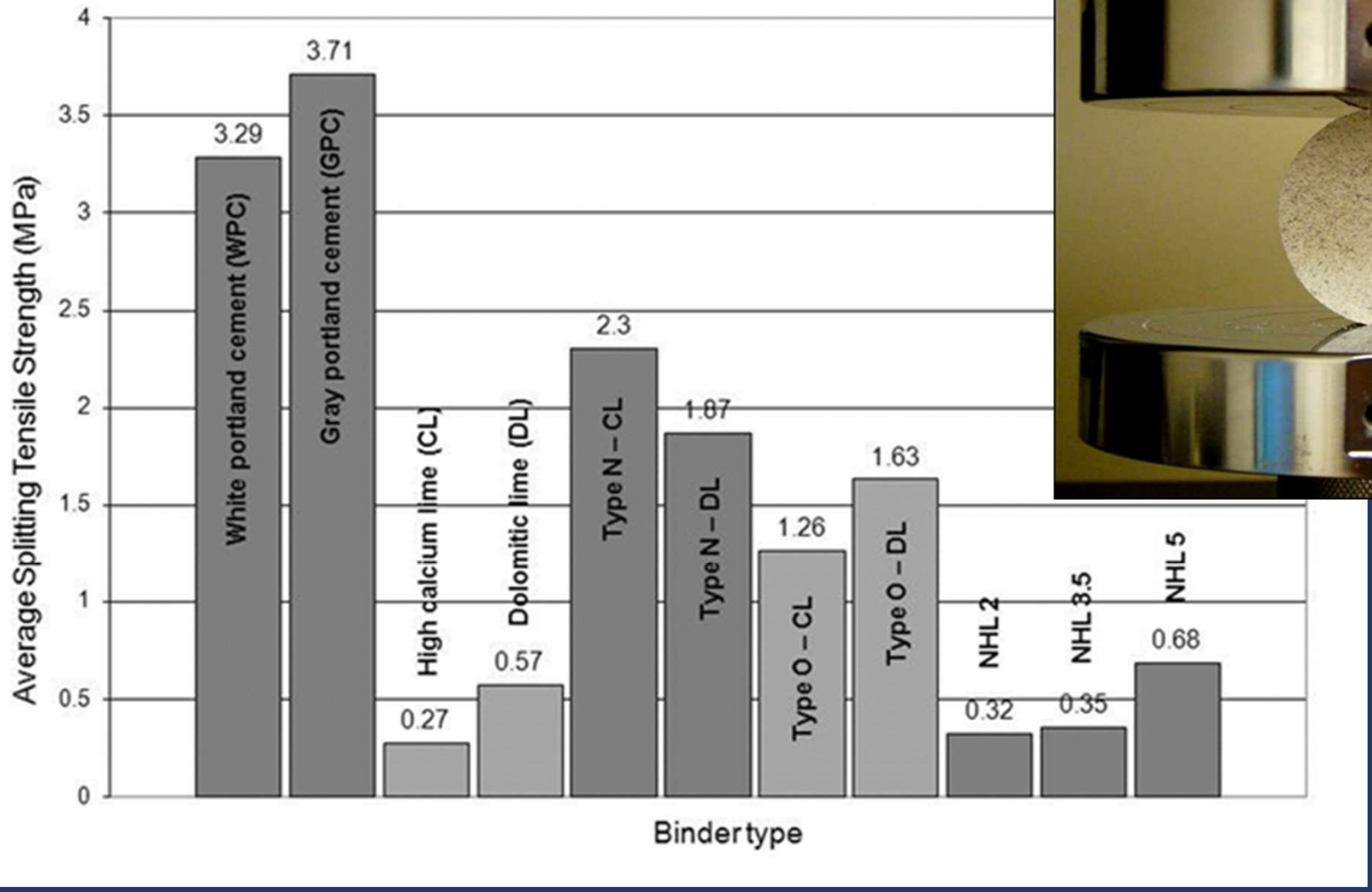
ave been made with a view of obtaining this information, e VII.).

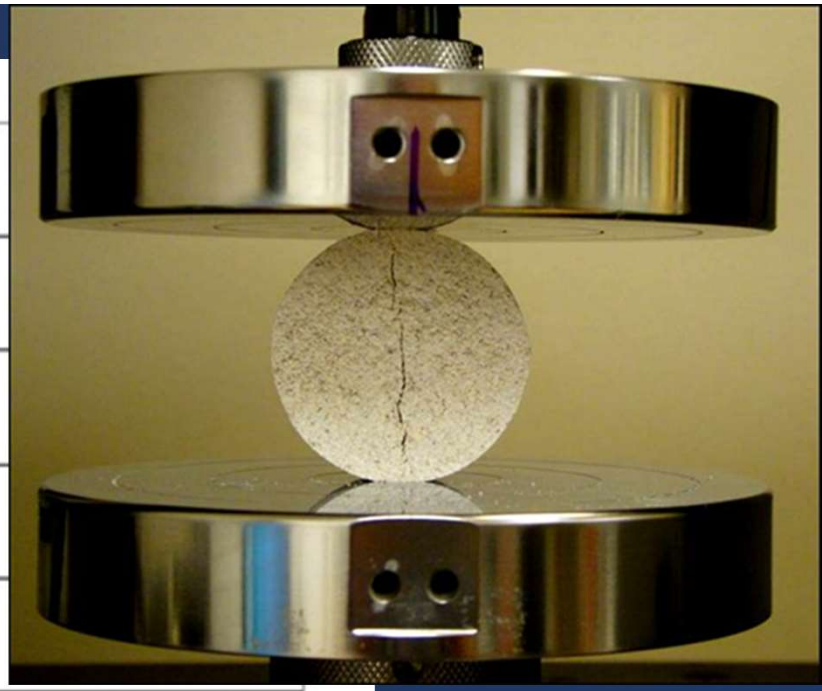
he same time that these tests were made, mortar was also o test pieces, and tested at the same age. We are thus enabled to form an idea of the relative strengths of mortar in thin joints and in cubes, and also to form an intelligent opinion of the comparative strengths of lime mortar, natural cement mortar, and Portland cement mortar. The mortars of the fourth, fifth, and sixth

But durability can be…

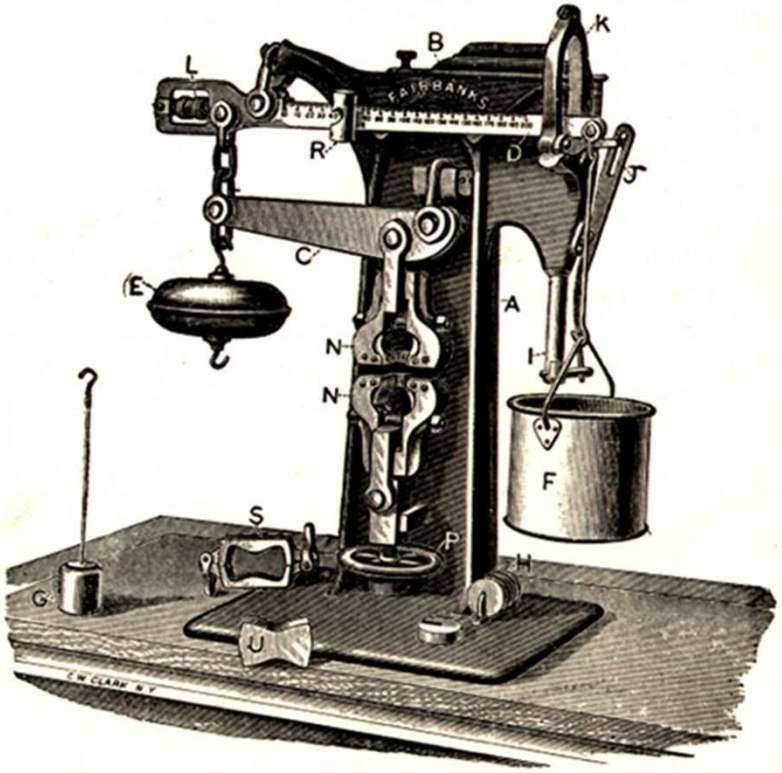
**structural durability
****materials durability**
****aesthetic durability**


200 GPM
800X
009454 15 kV x800 37.5µm


Average Splitting Tensile Strength (MPa)
4
3.5
3
2.5
2
1.5
1
0.5
0
3.29
3.71
0.27
0.57
2.3
1.87
1.26
1.63
0.32
0.35
0.68
White portland cement (WPC)
Gray portland cement (GPC)
High calcium lime (CL)
Dolomitic lime (DL)
Type N – CL
Type N – DL
Type O – CL
Type O – DL
NHL 2
NHL 3.5
NHL 5
Binder type



graduated beam, D., rises nearly to the stop K. A valve, J., is then opened to allow the shot to run into the cup, F., through the pipe, I., the shot continuing to run until the specimen is broken by the drawing down of the graduated beam, when the flow is automatically cut off by the valve. The valve itself forms one of the recent improvements of the machine, as it may be adjusted to permit of a larger or a smaller flow of shot, and the point of cut-off is arranged



THE FAIRBANKS CEMENT TESTING MACHINE.

TABLE 3—*Summary of average compressive strength values (psi).*

Type of Mortar	A	B	Improvement B over A, %	C	Improvement C over A, %	D	Improvement D over A, %	E	Improvement E over A, %
C 1:3 cement:sand....	6 235	7 601+	21.9	7 132	14.4	7 585	21.6	8 237	32.1
M 1:1/3:4 C:L:S.....	4 268	5 393	26.4	5 077	18.9	5 303	24.2	5 477	28.3
S 1:½:4½ C:L:S....	3 492	4 531	29.7	4 120	18.0	4 495	28.7	4 758	36.2
N 1:1:6 C:L:S.....	1 929	2 553	32.3	2 571	33.3	2 918	51.2	3 095	60.4
O 1:2:9 C:L:S.....	794	1 217	53.3	1 155	45.5	1 435	80.7	1 545	94.6
K 1:3:12 C:L:S.....	455	505	11.0	768	68.8	1 000	119.8	1 129	148.1
L 1:3 lime:sand.....	112	124	10.7	256	128.6	350	212.5	394	251.8

NOTE—A. 28-day laboratory curing.
B. 28-day laboratory curing plus 48 h drying at 122 F and 17% RH.
C. 3 months' exposure curing plus 48 h drying at 122 F and 17% RH.
D. 6 months' exposure curing plus 48 h drying at 122 F and 17% RH.
E. 12 months' exposure curing plus 48 h drying at 122 F and 17% RH.

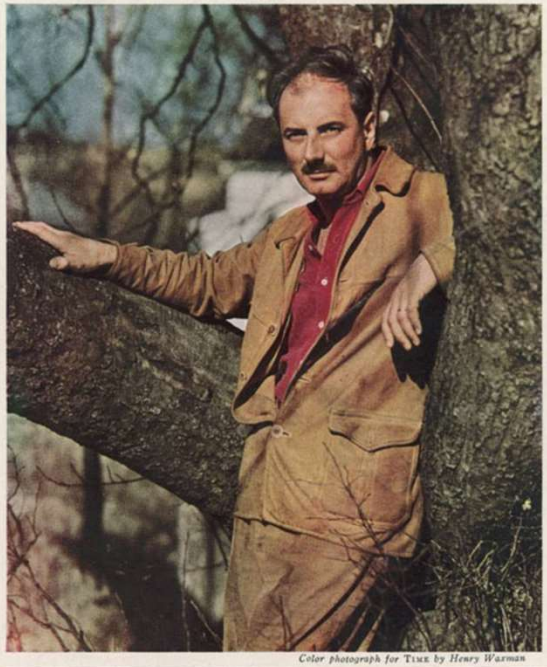
“Cements” include…

natural cements, “Roman” cements, lime-pozzolans, NHL’s, Portland cements, white cements, grappier cements, slag cements, fly ash cements….

FIFTEEN CENTS April 18, 1938

TIME

The Weekly Newsmagazine



Color photograph for TIME *by Henry Warman*

Volume XXXI

LEWIS MUMFORD

"The city is a collective work of art."

(See ART)

Number 16

Circulation Office, 330 East 22nd Street, Chicago. (Reg. U. S. Pat. Off.) Editorial and Advertising Offices, 135 East 42nd Street, New York.

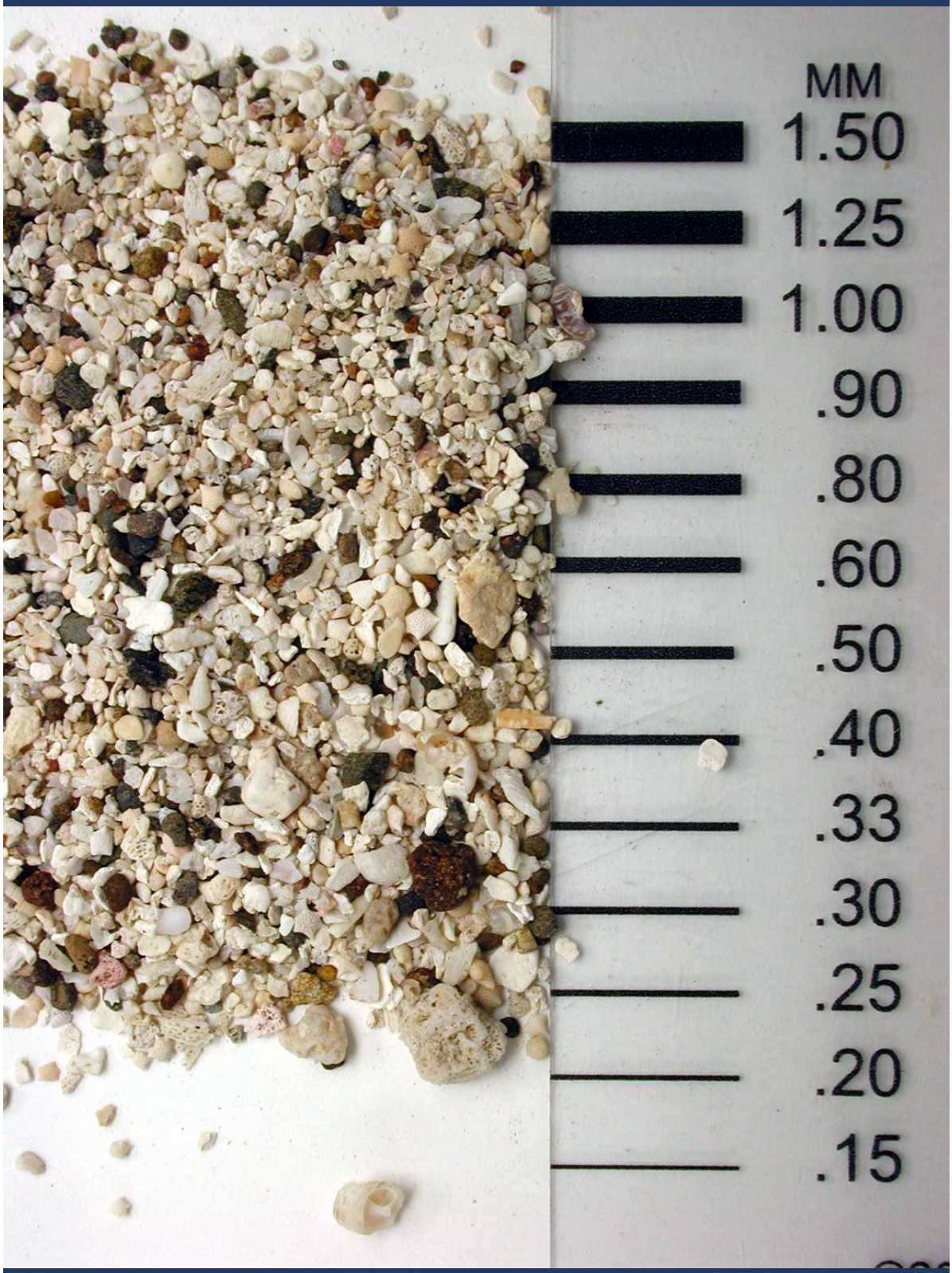
Durability **is the consistency of performance. And** ***performance*** **is in-service** ***behavior*** **over time.**

Durability **is the consistency of performance. And** ***performance*** **is in-service** ***behavior*** **over time.**

And ***behavior*** **(in the testing lab) is based on material** ***properties*****, isn't it?**

And *properties* = any/all measureable characteristics

= chemistry, mineralogy, microstructure (grain size/shape, porosity, pore size distribution, and so on).

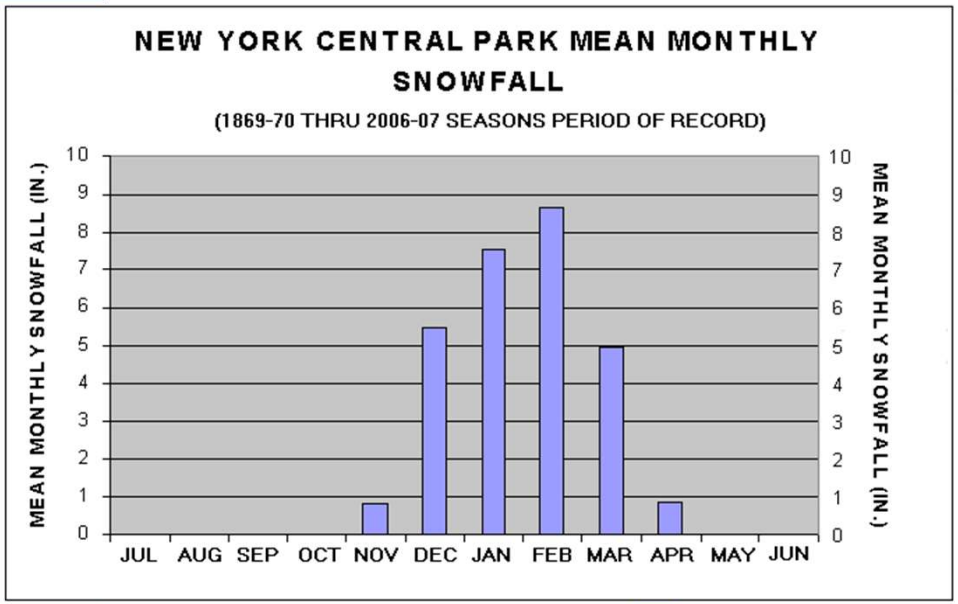

MM
1.50
1.25
1.00
.90
.80
.60
.50
.40
.33
.30
.25
.20
.15

But all of this--materials analysis and testing--is still in the laboratory, isn't it?

Performance **is based on properties + environmental exposure + construction technology.**

But all of this--materials analysis and testing--is still in the laboratory, isn't it?

Performance **is based on properties +** ***environmental exposure*** **+ construction technology.**



Access My Email | Columbia Univ

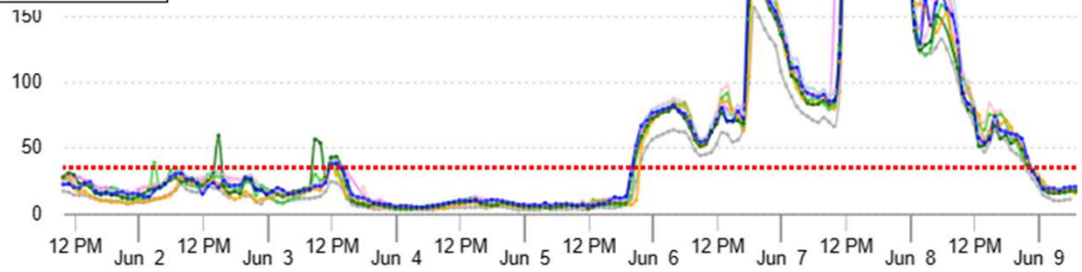
An Atlas of Dust: NYC air quality

Real-Time Air Quality in NYC | En

https://a816-dohbesp.nyc.gov/IndicatorPublic/beta/key-topics/air...

Show last days.

measurements (in µg/m³) | NAAQS 24-hour PM2.5 standard (35 µg/m³)

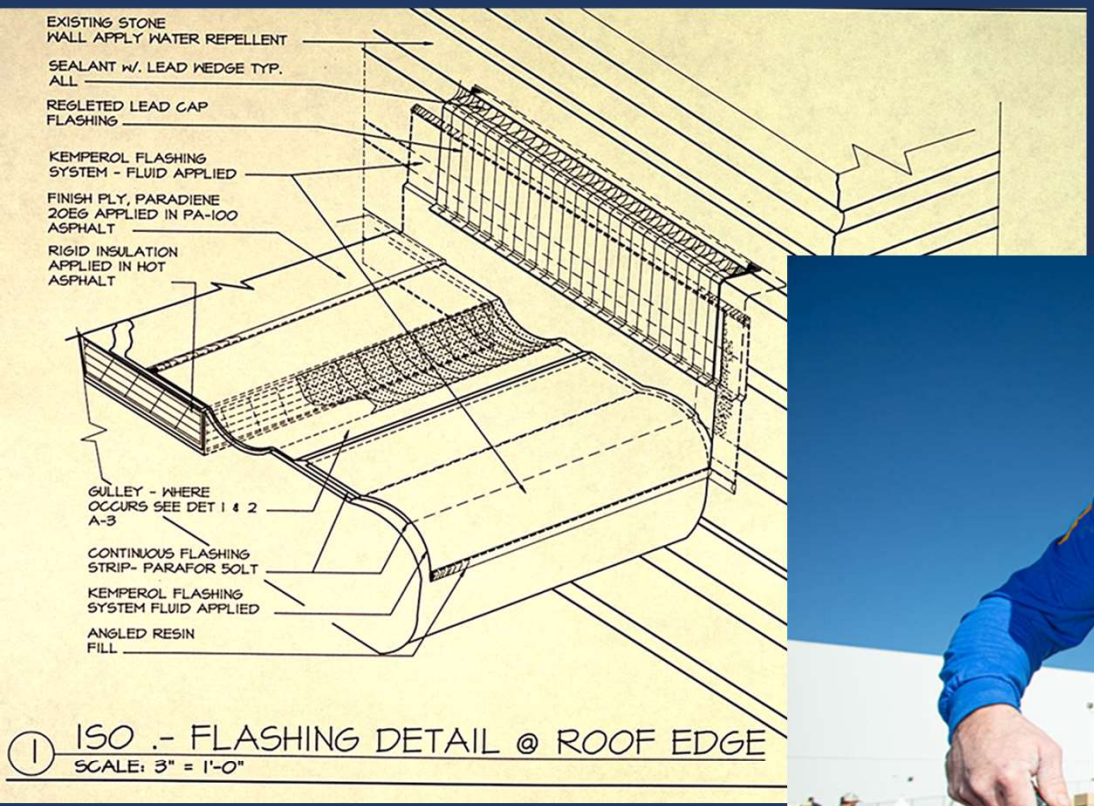


60°F Partly sunny

9:19 AM
6/9/2023

But all of this--materials analysis and testing--is still in the laboratory, isn't it?

Performance **is based on properties + environmental exposure +** ***construction technology*****.**



1 ISO .- FLASHING DETAIL @ ROOF EDGE

SCALE: 3" = 1'-0"


New & Improved

This is the EDSEL

"The emphasis is on engineering, but the accent is on elegance"

Edsel Citation 2-door Hardtop

The Edsel is as stylish in its performance as it is in its looks

The Edsel's classic vertical grille, its long lines, its graceful flight deck—all promise you a car beyond anything you have ever owned.

And the Edsel keeps its promise in every detail of performance.

The Edsel is powered by the newest V-8 engines in the world—the Edsel 400 and Edsel 475. Specifications: 400 and 475 foot-pounds of torque; 303 and 345 horsepower; 361 and 410 cu. in. of displacement; 10.5 to 1 compression ratio. You have never handled this kind of usable power before.

The Edsel's big, safer brakes need no periodic tightening. They adjust themselves automatically in the course of your day-to-day driving.

The Edsel shifts itself. In an Edsel equipped with Teletouch Drive, you just touch a button on the steering wheel hub. Teletouch Drive does the rest—smoothly, surely, *electrically*.

The Edsel's list of available new features is long. Examples: contour seats, a dial that lets you select temperature, quantity and direction of air with one twist of the wrist; a warning signal that flashes when you exceed your pre-set speed limit; another that flashes when oil is one quart low; a release that enables you to open the luggage compartment from the driver's seat.

You will find many things that make the Edsel different from any car you have ever driven. More exciting, more sure, more safe.

Edsel prices range from just above the lowest to just below the highest. You can afford an Edsel. And you can choose from four series—18 models. Your Edsel Dealer invites you to see and drive the Edsel—soon.

EDSEL DIVISION • FORD MOTOR COMPANY

1958

EDSEL

New member of the Ford family of fine cars