Granite and Precast Concrete Curbing Life Cycle Cost Analysis Update.

Final Report

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BACKGROUND AND STUDY OBJECTIVE

As government agencies and private developers face challenges to keep initial construction and recurring maintenance costs of highway curbing within project budgets annually, there is a strong, continuing interest to identify the most cost-effective alternatives. The objective of this study is to update and expand the economic analysis performed in 2006 on granite and precast concrete highway curbing (1). To assist in evaluating these two alternatives, life cycle cost analysis is employed to compare the initial and recurring costs over the life of each alternative. The data needed to conduct the life cycle cost analysis was acquired in a survey of state DOTs. This report includes three major sections: 1) results of the State DOT survey; 2) life cycle cost analysis; and 3) summary and conclusions.

SURVEY OF STATE DOTS

The Research Team obtained data on the extent of use and installation and material costs of granite and precast concrete curbing (PCC) in 12 states including Connecticut, Massachusetts, Maine, Nebraska, New Hampshire, New York, North Carolina, Rhode Island, South Carolina, Tennessee, Virginia, and Vermont. In some cases, bid pricing and volume information were available online and the sources of this information are provided in the list of references at the end of the report. The Research Team also obtained information directly from State DOT staff via email and/or by phone. In such cases, the source of the information is mentioned in the text. A summary of findings in each state is presented below.

Connecticut: Data provided by the ConnDOT Office of Administration/Policy/Estimating indicates that from 2018-2021 there were more than 80 completed highway projects on which either granite or PCC curbing was utilized. A total of 36 projects was selected for further analysis including 8 with granite and 28 with PCC each of which had a minimum of 200 linear feet and an average length of just over 1000 linear feet. Depending on the location, type of roadway, size of the project, and other factors, the cost per linear foot including material and installation ranged from $40 to $72 per linear foot for granite and from $21.50 to $85 per linear foot for PCC. Average values estimated by the Research Team are $36 per linear foot for PCC and $58 per linear for granite.

Georgia: According to the GDOT Bureau of Office of Engineering Services staff, poured in place concrete is accountable for 90 to 95 percent of curbing on state highway projects primarily due to ease and speed of installation, while granite is installed on a limited basis on smaller projects in historic areas. PCC is not used at all.

Massachusetts: An analysis of the MassDOT Highway Division Construction Price Estimator Database (2) for 2018-2021 indicates that there have been more than 100 completed projects which include 92 with granite curbing and 8 projects with PCC. The total length of a single granite curbing project varies from 6 to 10,000 feet; 82 of the granite projects were between 6 and 1692 feet. The total length of PCC curbing projects ranges between 5 and 380 feet; 4 of these concrete projects were between a 5 to 80 feet category. It is clear that granite curb material is more widely used on MassDOT highway projects than is PCC and granite is also typically used on larger projects. Granite curb bid prices including material and installation ranged from a low of $25 per

linear foot to a high of $75 per linear foot depending on the location, type of roadway, size of the job, and other factors. The PCC bid prices ranged from $23.50 to $70.50 per linear foot. Average values estimated by the Research Team are $44 for PCC and $52 for granite.

According to MassDOT Highway Division District 2 construction staff, a major reason for selecting granite curb material versus PCC relates to the context and physical environment in which the roadway is located. For example, in a downtown area of a small or medium-size city or town granite may be the preferred option because it blends in better aesthetically with the existing streetscape and surrounding area. The staff also acknowledged the apparent lack of extensive precast standards in Massachusetts as compared to the standards that exist for granite which may be another reason why granite is chosen more often over precast.

Maine: Based on an analysis by the MaineDOT Contracts Section Database of contracts awarded in 2018-2020, the average winning bid price for the linear foot of granite curb was $54 up from the $50 bid price of 3 years ago (3).

Nebraska: The NDOT Unit Price and Letting Database from July 2020 through June 2021 reveal that for PCC the cost was $35.35 per linear foot for multiple projects totaling more than 4000 linear feet. No bid information on any contracts for granite curb was found in the database for the last five years (4).

New Hampshire: The 2020 NHDOT Weighted Average Unit Price Database indicates that for granite curbing on rural projects over $750,000 the weighted average was approximately $28 per linear foot. According to NHDOT staff, concrete curbing is not used in NHDOT contracts (5).

New York: An analysis by the Research Team of the NYSDOT database indicates that the average bid price for PCC curbing was $42.00 per linear foot, while granite was also approximately $42. It should be mentioned that the PCC has been used on small projects (less than 200 linear feet), and hence is not representative of a cost for PCC on other size projects.

North Carolina: According to the NCDOT highway design staff, poured in place concrete is almost exclusively used for curbing on state highway projects, granite is used on a very limited basis on small projects, and PCC is rarely used.

Pennsylvania: According to the PennDOT Bureau of Construction & Materials staff, poured in place concrete is accountable for the majority of curbing on state highway projects, while granite is installed on a limited basis on smaller projects in historic areas. PCC is not used at all.

Rhode Island: An analysis by the Research Team of the RIDOT Project Management Portal indicates that the average price from 2017 to 2021 for granite curb was $80 with the bid price range from $60 to $100 per linear foot. It should be noted that the projects where granite was used were small (less 200 linear feet) and may not be representative for other size projects. According to the RIDOT Portal, no PCC was used during this time period (6).

South Carolina: According to the SCDOT Specs and Estimates Engineer, granite is not used as curbing material in SCDOT projects and PCC is used but only to a limited extent for maintenance purposes.

Tennessee: Based on an analysis by the Research Team of the TDOT Construction Division Price Information Web Portal, the weighted average bid price per linear foot for PCC was $42 for a single project just over 200 linear feet. According to the Portal, granite curbing is not used in TDOT contracts and it appears that the major curbing method in Tennessee is poured in place concrete (7).

Virginia: According to VDOT Cost Estimation Office staff, granite curbing is not used in VDOT contracts and PCC is used at an average unit price in 2020 at about $40 per linear foot.

Vermont: An analysis of the VTrans five-year average price list dated July 2015 through June 2020 (8) indicates that granite curb has been used 10 times more often (30 projects vs 3) than PCC. The average unit cost of granite curb was $50 per linear foot while the average unit cost for PCC was$53 per linear foot. It should also be noted that the size of the PCC projects was quite small and consequently the unit price for PCC may not be representative for other size projects.

A summary of the types of curbing used and the average unit cost data is presented in Table 1.

Table 1 Summary of the PCC and Granite Curb Average Installation and Material Costs

STATE	YEAR	PCC CURB UNIT COST, US DOLLARS PER LINEAR FOOT	GRANITE CURB UNIT COST, US DOLLARS PER LINEAR FOOT
CT	2018-2021	36	57
GA	2017-2021	Use poured in place concrete	43
MA	2018-2021	44	52
ME	2018-2020	Not used	54
NC	2019-2021	Use poured in place concrete	Very limited use
NE	2020-2021	35	Not used
NH	2020	Not used	28
NY	2019-2020	42 (small projects)	42
PA	2017-2021	Use poured in place concrete	130

STATE	YEAR	PCC CURB UNIT COST, US DOLLARS PER LINEAR FOOT	GRANITE CURB UNIT COST, US DOLLARS PER LINEAR FOOT
RI	2021	Not used	80 (small projects)
SC	2019-2021	Use poured in place concrete	Not Used
TN	2020	42	Not Used
VA	2020	40	Not Used
VT	2015-2020	53 (small projects)	50

As can be observed from Table 1, the cost per linear foot of the same type of curb varies significantly between State DOTs, and this variation is associated with the geographic location, type of roadway, size of the project, availability of the curbing material, and other factors.

LIFE CYCLE COST ANALYSIS

The life cycle cost analysis will employ the net present value (NPV) method which requires estimates of the initial installation and material costs, recurring costs, curb life expectancy, and an assumed discount rate as discussed below. In addition, the LCC analysis will consider other costs that are difficult to quantify in monetary terms but are important to consider; these costs include curb damage, construction delays to road users, aesthetics, and the curbing salvage value.

Initial Costs: The survey of State DOTs and a review of local and state bid records as presented above were conducted to assist in determining the initial costs of granite and precast PCC curbing. As can be observed in Table 1, the average of the initial curbing costs of granite is generally higher than the initial costs of PCC, and the costs vary depending on State location, size of the job, availability of the curbing material, and other factors. The outlier values often tend to be associated with very small or very large highway construction projects and consequently these values will be removed from the LCC analysis in order to facilitate the conduct of an NPV analysis that represents typical projects of the size ranging between 200 and 5,000 linear feet. If the outliers in Table 1 including costs of granite in NH, RI, and PA and PCC in VT are disregarded, the initial granite costs range from an average of $42 per linear foot to $58 per linear foot and the PCC ranges from an average of $35 to $44 per linear foot. Based on these ranges, the Research team then computed an overall average initial cost of $40 per linear foot for PCC and $50 per linear foot for granite.

Recurring Costs: There are three recurring costs that can be examined with some degree of certainty: preventive maintenance, replacement, and disposal of a worn-out curb. Other recurring costs, such as repair of curb damage, are random and prove difficult to quantify. Costs of this nature will be addressed later. Properly installed granite curbing requires no maintenance. Concrete

curbing, after proper installation, requires periodic sealing to extend its life. However, this maintenance is seldom, if ever, performed. In addition, it is difficult to establish an accurate cost for this kind of maintenance. It is realistic to assume no maintenance will be performed on the concrete curbing. This lack of maintenance will be reflected in shorter life expectancy than attainable with ideal care.

At the end of its life, the concrete curbing will have to be removed, discarded, and replaced. Recycling the PCC curb is not economically feasible at this time because of the labor required to remove the reinforced rod. The cost to dispose of deteriorated curbs has risen dramatically in recent years. In 1988 the Massachusetts DPW paid, on average $1.96 a linear foot to remove and discard the curb (9). Current prices to remove and discard are often exceeding $5 per linear foot (10). Disposal prices will continue to rise faster than other prices as the remaining landfill space becomes more valuable.

Life Expectancy: Granite has an "indefinite" life expectancy. Granite curb can be removed and reset when curb reveal is diminished due to road resurfacing. Structural properties of granite curb also allow it to be left in place during road milling operations, a popular highway maintenance treatment. Road milling is an especially attractive alternative to reconstruction in urban areas. In these locations, road height is limited by the height of building sills and bridges. At some point additional overlays become impossible. When there is a good base present, road milling is less expensive than tearing up the old pavement and reconstructing the roadway. It is also quicker and permits continued use of road resurfacing. This factor is especially important for major arterials and collectors.

Concrete curbing has no salvage value. It is subject to breakage during removal operations which are very common today given that many state and local highway agencies are implementing large-scale pavement management and maintenance programs. It is typically removed, discarded, and replaced when its reveal is lost. By this time, it has usually deteriorated to a point where it cannot be reinstalled even if some life remains and if it could be removed intact economically. Concrete is prone to damage during milling operations because of its low strength and abrasion resistance. Extreme care must be taken to avoid damaging it. This extra care means greater milling expenses.

In actual application, a PCC curb's useful life is often dictated not by its own life but rather by the life span of the road. It makes sense to replace the deteriorating PCC curb while the road is being rehabilitated. If PCC does not last as long as the road, curb replacement requires tearing up part of the road. This necessitates patching, which in practice, seldom yields quality comparable to the original construction, but often leads to premature deterioration of the roadway. Two life expectancies of PCC will be examined, ten and twenty years.

The twenty-year life expectancy is based on a study by the Rhode Island Department of Transportation (11). The twenty-year life span is consistent with the design life of many urban roads. Precast PCC curb is normally replaced in conjunction with reconstruction.

The ten-year life span is included in the analysis to show what the life cycle cost would be if the PCC curb did not last twenty years. Lab testing indicates this possibility should not be ruled out, especially if the PCC curb is being considered for installation in a region, which experiences harsh winter conditions resulting in a variety of aggressive road treatments. For example, according to Aspen, Colorado, engineering department, granite's estimated useful life of 60-plus years while only 10 to 12 years for concrete (12).

Net Present Value Analysis: The analysis considers initial and recurring curbing expenses on a linear foot basis over the life of a newly constructed or reconstructed road and a forty-year planning horizon is assumed. The analysis will be conducted with discount rates of 7, 5, and 3% to examine the impact the discount rate has on the estimated net present values of PCC. It should be noted that these discount rates are higher than the current discount rate being considered by the U.S. Office of Management and Budget (13).

Assuming a 7% discount rate has been used by U.S. Federal agencies (14) and a PCC curb life of twenty years, expenses will consist of $40.00 immediately (year 0) and $45.00 ($5.00 to remove and discard + $40.00 to replace) in year twenty. Curb replacement at the end of year forty is not considered. The net present value (NPV) of these expenses is $51.63. The granite curbing can be left in place during projected road milling and rehabilitation in year 20 or so it is assumed that there will be no other expenses during the forty-year planning horizon. The NPV of granite is, therefore, $50.00. Under such assumptions, when the inevitable future expense of replacing deteriorated precast PCC curb is considered, the NPV of PCC is marginally higher than the granite. However, under the assumption that the precast curb lasted only 10 years, its NPV would be about $85 compared to granite's $50, and granite will clearly become a lower-cost alternative. Table 2 presents a sample calculation of New Present Value (NPV) using a twenty-year life expectancy of PCC curb, a 7% discount rate, and a forty-year planning horizon.

Table 2 Precast PCC NPV Calculation at 7% Discount Rate and a PCC Life of 20 Years

YEAR	INITIAL COST	PWF	PW
0	$40.00	1	$40.00
20	$45.00	0.258	$11.63
		NPV	**$51.63**

Notes: **PWF** = Present Worth Factor = 1/(1+ r)t; **PW** = PWF x expense, where r = discount rate and t= time period (year)

When this analysis is conducted at a 5% discount rate which has been advocated in the past by the Portland Cement Association (15), the NPV of PCC and granite would be about $57 and $50, respectively, as shown in Table 3 for the twenty-year life of PCC. The NPV of PCC would be almost $100 per linear foot if it lasted only 10 years, which would make it twice as expensive as granite.

Table 3 Precast PCC NPV Calculation at 5% Discount Rate and a PCC Life of 20 Years

YEAR	INITIAL COST	PWF	PW
0	$40.00	1	$40.00
20	$45.00	0.377	$16.96
		NPV	**$56.96**

When a 3% discount rate consistent with past studies (1, 13) and lower than is currently being considered in public infrastructure investments (12) is used, the NPVs of PCC and granite are $64.92 and $50.00, respectively, for a twenty-year PCC life span, a difference of about 30%. If PCC lasted only 10 years its NPV would be about $122 per linear foot, almost two and a half times more than granite.

Table 4 Precast PCC NPV Calculation at 3% Discount Rate and a PCC Life of 20 Years

YEAR	INITIAL COST	PWF	PW
0	$40.00	1	$40.00
20	$45.00	0.554	$24.93
		NPV	**$64.92**

Figure 1 provides a graphical representation of the results of the NPV analysis under different discount rate and PCC life scenarios, a planning horizon of forty years, and a current average cost per linear foot of $40 for PCC and $50 for granite. Under no scenario is PCC a better choice over granite in terms of the NPV and due especially when taking into account that the current real discount rate being employed by the U.S. Office of Management and Budget is less than 1% (12). When other important costs which have not been considered in the NPV analysis are acknowledged, it becomes even more clear that granite is the superior choice as explained in the section below.

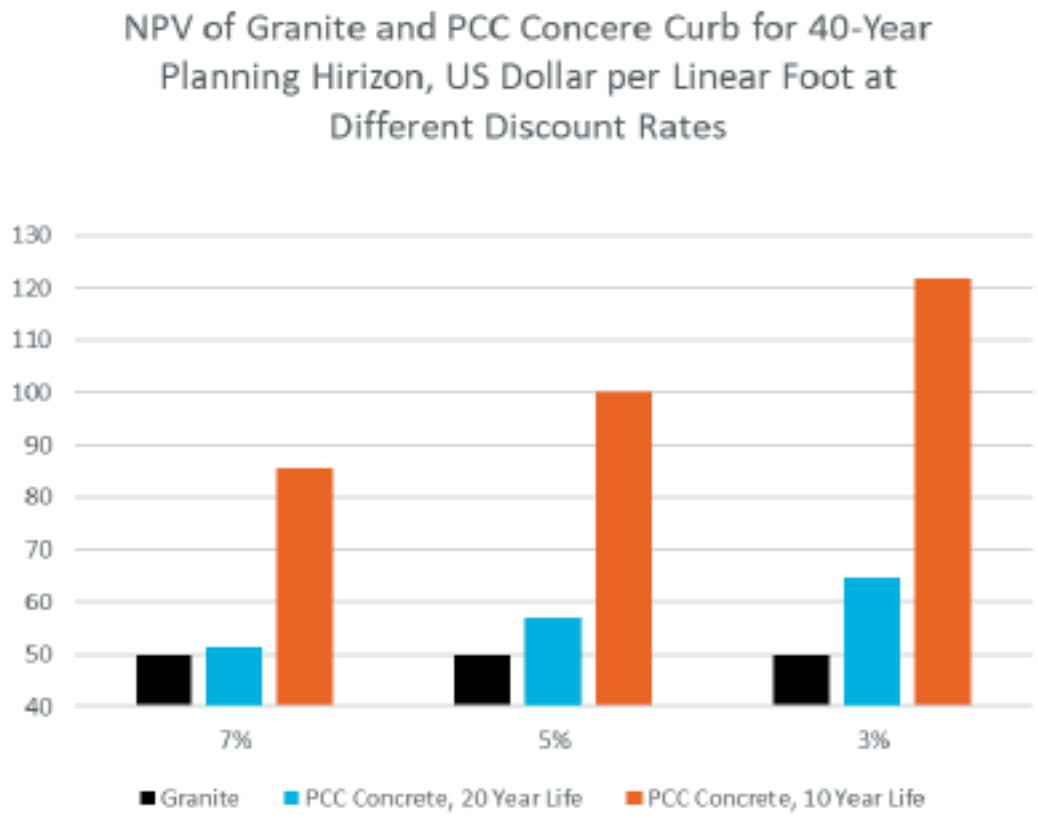

Figure 1. NPV of the Granite and PCC Concrete Curb

Other LCC Costs and Environmental Impacts: The NPV method is a useful tool but not adequate by itself to fully assess the relative costs of granite curbing versus PCC concrete because the NPV analysis as presented above does not include costs such as curb damage, construction delays to road users, aesthetics, and the salvage value of granite all of which work in favor of granite.

Curb damage is typically inflicted on the PCC curb by rollers, snowplows, and heavy trucks. Granite curb, however, has a legendary resistance to this kind of damage. Granite curb was assumed to be worth nothing at the end of the forty-year planning horizon. Granite curb, which was laid at the turn of the century, however, is routinely salvaged and reused. The granite curb laid today will be around for generations. The fact that granite curb is reusable, rather than a disposable commodity, will undoubtedly become more important in the future. When the days of abundant and inexpensive landfill space are over, recycling is rapidly becoming a necessity. In Western Massachusetts, 85 cities and towns that joined a regional recycling facility, rather than constructing expensive new landfills, were required to adopt mandatory recycling laws (16). Similar arrangements are being adopted across the country. Environmental concern had become a pressing national issue and a structural switch from disposable to reusable commodities is an integral part of the solution.

While the NPV method employed in the analysis incorporated the cost of discarding PCC (and acknowledged the consequence of not requiring the need to recycle old granite and consume scarce land at recycling and landfill facilities), the analysis does not address other environmental impacts associated with the alternative curbing materials. These other impacts relate to, for

example, sustainability, climate change, energy consumption and carbon emissions associated with the mining and manufacturing of curbing materials. In order to further compare alternative curbing materials with respect to these environmental impacts a more detailed, quantitative and qualitative evaluation would need to be conducted. This evaluation would attempt to assess these impacts using monetary and non-monetary metrics as well as possibly qualitative criteria.

SUMMARY AND CONCLUSIONS

The LCC analysis indicates that when the inevitable replacement of PCC is considered and major costs are taken into account, granite curb is a more cost-effective curb material. The only advantage of using PCC curb is its lower initial cost. This advantage is negated, however, by granite's durability, longevity, and reusability as well as the relatively low discount rates currently being employed to evaluate public sector investments (12). In addition, it should be stressed that a physical comparison clearly indicates that granite is a superior curb material, especially in areas with a colder climate, where winters, road salt, and plowing are tough on PCC.

The conclusions of the LCC analysis are also strengthened by a continued rise in costs to dispose of a deteriorated curb. The disposal crisis is a disturbing, expensive reality, which cannot be ignored. Part of its solution seems to be a general trend toward reusable versus disposable commodities. Granite curb represents a good example of a reusable commodity. It is the decision of elected officials which determines whether future generations will be left with continual curb replacement expenses or stock of long-lasting durable and reusable curb.

The results of the LCC analysis including the use of the NPV method coupled with the consideration of costs of curb damage, construction delays to road users, aesthetics, and the salvage value of granite show that granite can be the superior choice over PCC under current economic conditions especially when the infrastructure of most of the country has been burdened by a backlog of deferred maintenance (1, 17).

Because there are a significant number of state DOTs which widely implement other methods to construct highway curbs, such as cast-in-place concrete, slip-form concrete, and asphalt berm curbing alternatives, it is recommended that a follow-up study be conducted including these other curbing alternatives. Furthermore, in light of rising environmental concerns associated with infrastructure projects, it is recommended that a more detailed quantitative and qualitative environmental assessment be carried out using monetarary and non-monetary metrics.

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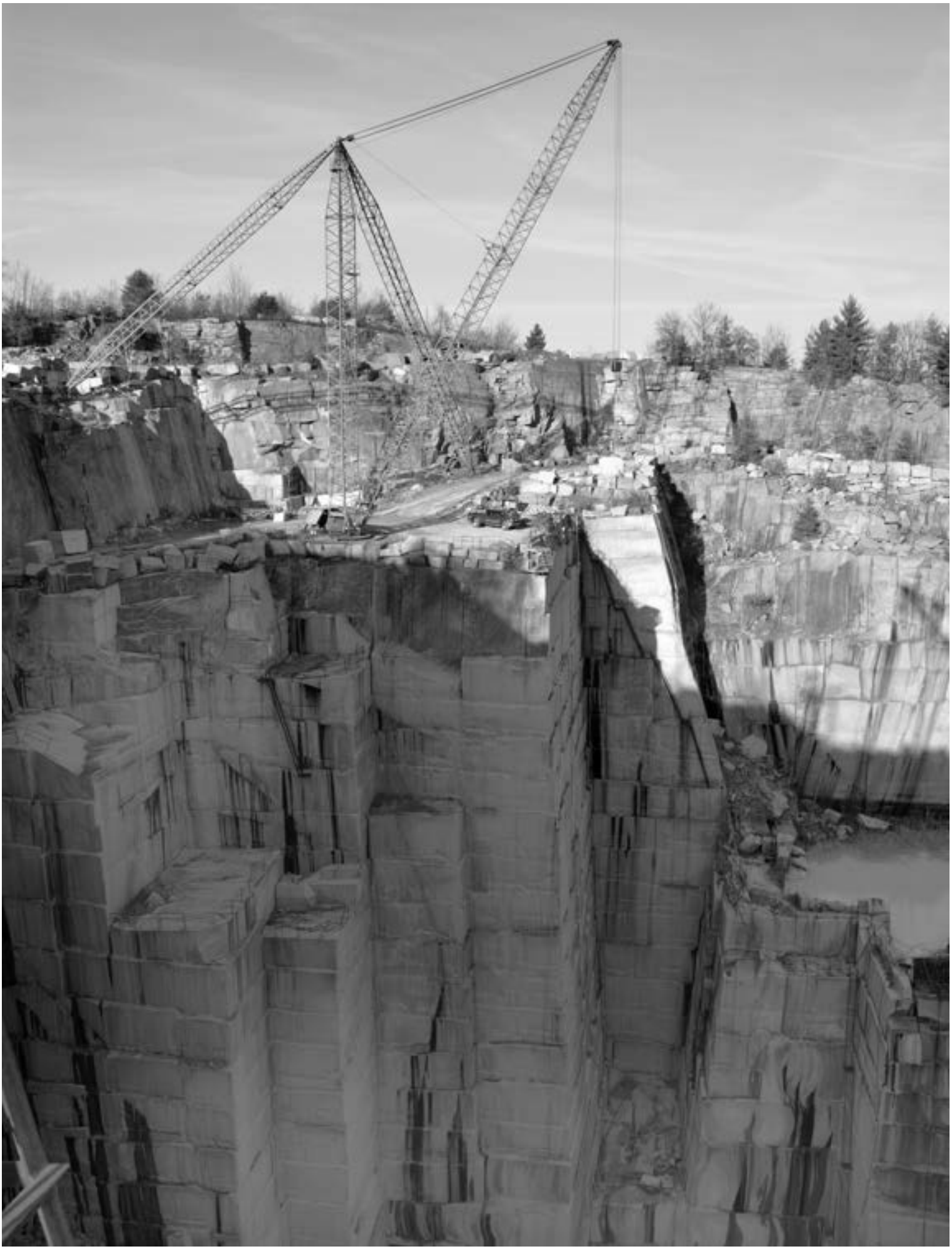

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