


Structural Analysis Comparison

GRANITE AND PRECAST CURBING

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INTRODUCTION

Curbs deter vehicles from leaving the pavement, control drainage, and support the edge of the pavement. It should be noted that once established, most roadways remain unaltered for generations. Therefore, curbs are expected to serve long lives. They must be durable, and at the same time economical.

This report is a comparative analysis of granite and precast Portland cement concrete (PCC) curbing. In order to determine the most durable and cost-effective material for roadway curbing the physical properties of the materials, as well as their costs, must be examined.

The physical property comparison considers the durability of the curb materials as they are subjected to detrimental conditions inherent in the curb's environment. These conditions include the application of road salt and freeze/thaw action.

SUMMARY

Physical comparisons between granite and precast Portland cement concrete (PCC) curb indicate that granite is a superior curb material. An economic analysis further determines that granite curb also is a cost-effective curb material. Although the cost of precast PCC curb is less than that of granite curb, granite's durability, longevity and reusability negate the cost advantage of precast PCC.

PHYSICAL COMPARISON

There are many varieties of granite and PCC. This report will examine the properties of curb-quality granite from the major quarries on the east coast and today's high-quality 5000-6000 psi, low-slump, air-entrained, precast PCC curb, The properties of this precast PCC curb are more uniform, and far superior than those of typical cast-in-place or even extruded-in-place PCC curb. It should be noted that not all precast PCC curb meets these specifications.

The principal factors that affect the life span of curbs are loads, impacts, and the elements. The most destructive elements in the Northeast, as previously stated, are salt and freeze/thaw action. The ability of the curb to resist loads and impacts decreases with exposure to the elements.

Lab tests have shown that granite is stronger, and more resistant to the elements, than precast PCC. Granite curb is routinely salvaged and reused. Granite curb also withstands road milling, a common maintenance technique. Granite curb can serve a nearly indefinite life – at least by human standards.

PCC curb, however, deteriorates over time. Deterioration generally occurs at a greater rate along the back of the curb. This is due to the availability of moisture against this face. The back of the curb, which has less opportunity to dry off, is saturated during more freeze/thaw cycles than the front. The result of this deterioration is that the curb's appearance may conceal its true condition. When weakened curb is subjected to an impact, the collapse is sudden and complete.

Because the precast PCC curb that this report is examining has not been in common use very long, lab testing was required to determine its durability. Lab testing also allowed samples of granite and precast PCC to be exposed to the same controlled simulation of a curb's environment. While the granite curb showed no adverse effects, precast PCC curb subjected to salt exposure and repeated freeze/thaw cycles during lab tests deteriorated around the edges. The strength of precast PCC samples can be tested until there is nothing left to test. At some point, however, a subjective judgment must be made as whether the precast PCC still serves the purpose of a curb.

TEST RESULTS

Very simply, durability is the quality of being able to endure (1). This is typically evaluated in terms of the ability of the material to maintain sufficient strength and resist breakdown so that the curbing may perform its intended functions. There are three main factors that are generally considered in the durability equation, namely climatic conditions, service and exposure conditions, and maintenance requirements.

Climatic Conditions

Durability under climatic conditions may be assessed by considering strength changes during weathering, with the most serious being the mechanical weathering associated with freeze/thaw and de-icing salts. Freeze/thaw cycles contribute to both reduction in strength and surface scaling in concrete (2). Recent studies on concrete and granite curbing (3) indicate that both granite and concrete test specimens endured 450 freeze/thaw cycles. However, no change occurred in the appearance of the granite compared to the concrete that showed sharp deterioration in appearance; particularly the corners and edges that were rounded as a result of spalling. The modulus of the concrete determined by sonic measures decreased to zero while that of the granite retained half of the original value.

Laboratory determination of durability characteristics related to tensile strengths of granite and precast PCC showed a reduction of tensile strength by freeze/thaw cycles. The lowest flexure modulus of granite (397 psi) was found to be 15% higher than the highest precast PCC flexure modulus (357 psi) after 450 freeze/thaw cycles. It can be deduced that if PCC curbing's strength decreases for any reason then it could become inadequate to withstand impacts.

Service and Exposure Conditions

Granite is reported as a natural material, very resistant to scratching and heat, and thus granite has a sense of timelessness (5), that is, it lasts far longer than man.

Chemical de-icing agents used on highways also can affect the durability characteristics of concrete and granite. Salt weakens concrete used in pavements (6). A study by Maguire included immersion of concrete and granite in various salt solutions. This resulted in reductions of compressive strength between 25.1% to 74.4% for concrete, whereas reductions in the compressive strengths of granite were only 0 to 3.41% (4). Recent studies comparing the weathering resistance of precast PCC and granite by cyclic immersion in various chemical solutions yielded similar results (7).

De-icing salts also can cause weight loss in curbing materials. Cyclic immersion in salt solutions and drying cause surface scaling in concrete (2). A recent study included cyclic immersion of granite and precast PCC samples in ammonium sulfate and ammonium nitrate solutions. After 40 cycles of immersion and drying, the precast PCC weighed, on average, 10% and 50% less, respectively, while the weight loss of granite was negligible.

A properly installed and fully supported curb 18 inches by 6 inches by 8 feet in size would have to resist a tensile or compressive stress of 360 psi under a wheel load of 10 kip. Weathered concrete and granite, however, can typically resist 4000 psi and 22,000 psi, respectively, in compression. Both materials, however, are far weaker in tension and a realistic factor for concrete would be U10 or 1f12 of the compression strength. The tensile strength would then be approximately 360 psi, which is of the magnitude caused by a 10 kip load, so failure is possible.

The tension factor of granite may be smaller than that of concrete, but even assuming tension as low as U20 of the compressive strength would still give an allowable stress of 1100 psi. This is well above that brought about by a heavy wheel load. If this load is, however applied with some impact, an increase in stress will result. This is likely to cause the concrete curb to crack whereas the granite curb will probably withstand this impact.

Historically, granite has a very long service experience record under a wide variety of usages and exposures. "The obelisks of ancient Egypt and other monumental structures stand as mute testimony to the lasting and durable nature of stones of the granite family." (4)

Maintenance Requirements

Surface applications of silicones, linseed oil, asphaltic and oil-based paints, tai, wax and plastics on concrete curbing have been moderately successful in delaying damage. Curbs, however. generally are not maintained after construction.

Considering the recycling of curbing material, most highway construction specifications call for granite as a curbing material where salvaging and reuse during highway widening and construction are considered.

Reuse of granite is enhanced as it can be cut into different widths and shapes (5). Granite also is used as a facing for precast concrete curbs (8).

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6. Trost, S.E., Heng, F.J., Cussler; E.L., “Chemistry of Deicing Roads; Penetrating Ice”. ASCE, Journal of Transportation Engineers, Vol. 114, November 1989.

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8. Massachusetts D.P.W. Specification, March 1977.

PHOTOGRAPHS

This appendix contains photographs that highlight selected features of concrete and granite curbing discussed within the body of this report. Included are standardized granite curbs like those of regular vertical curbs and vertical curb inlets. Other photographs show the features of granite curbing which make granite curbing more effective than concrete curbing. There are also photographs that illustrate some of the problems associated with concrete curbing. The photographs were taken in eastern and western Massachusetts.

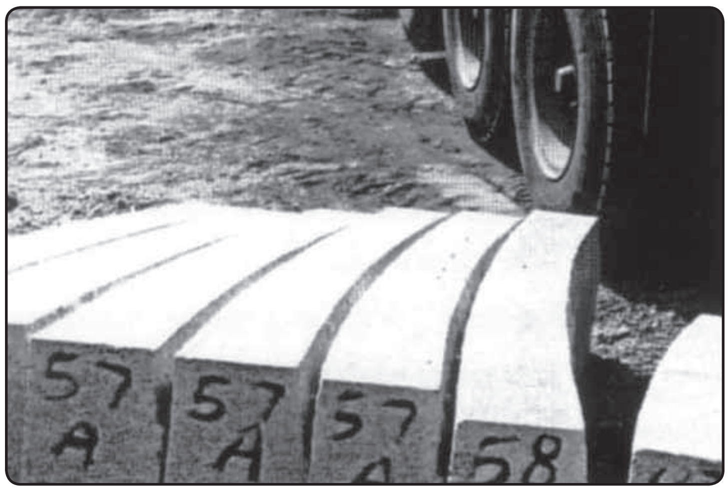

FIGURE 1: Standardized granite vertical curb (radius).

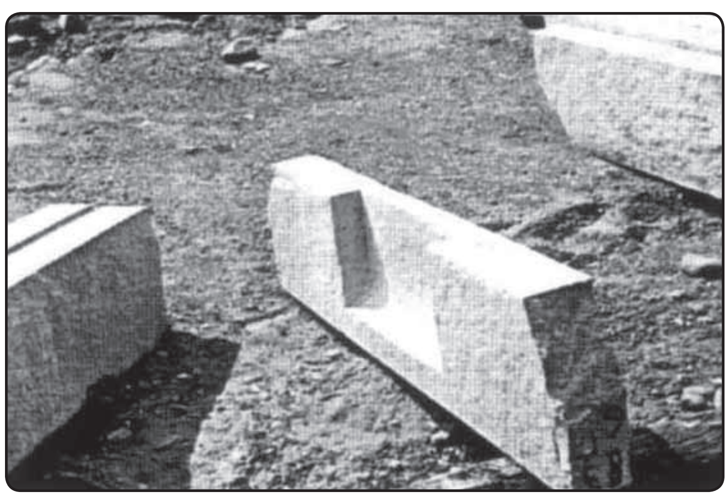

FIGURE 2: Standardized granite vertical curb inlet.

FIGURE 3: Modern machinery and methods produce granite curbs with neatly sawn tops and smooth split faces, adding to the aesthetic appearance of pavement.

FIGURE 4: Due to its long life span, granite curb can be removed and reset to a new line or grade.

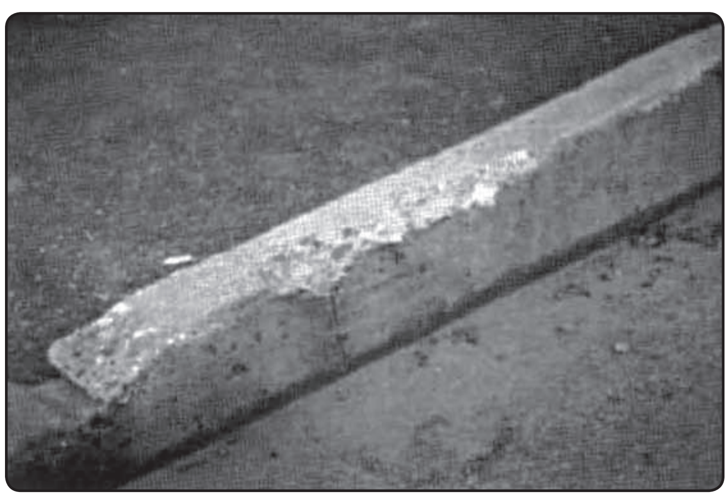

FIGURE 5: Concrete in the long run is susceptible to problems such as spalling.

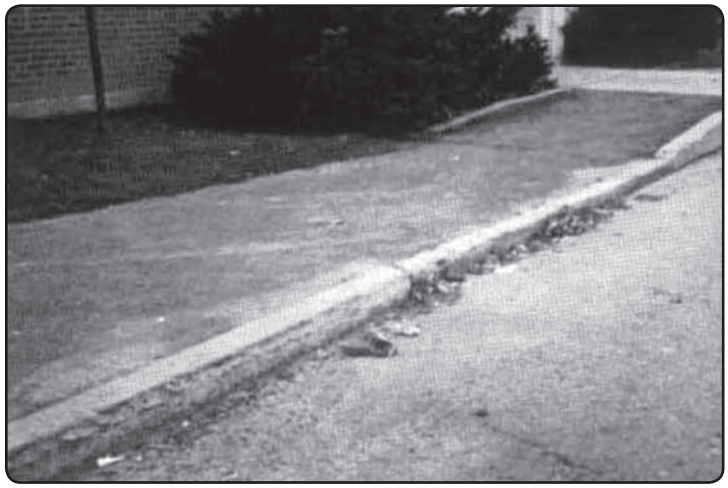

FIGURE 6: Comparative view of granite (to the left) and concrete (to the right) curbing.

FIGURE 7: View of a completely deteriorated concrete curb.

FIGURE 8: Eighty-year old granite and new precast concrete samples subjected to freeze/thaw testing.

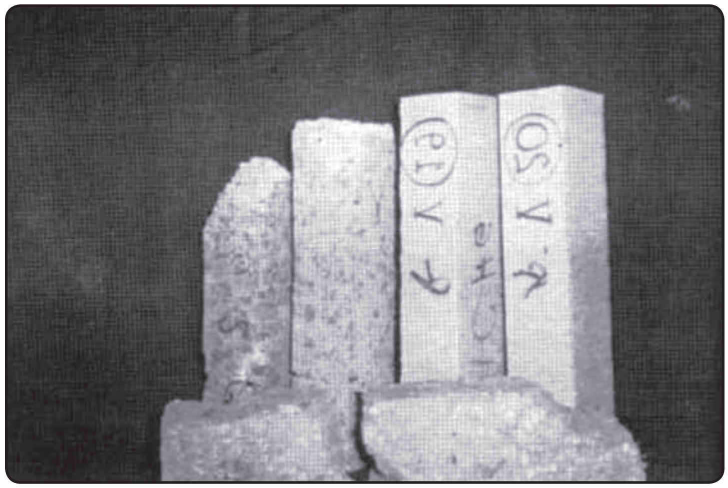

FIGURE 9: New granite and new precast concrete samples subjected to freeze/thaw testing.

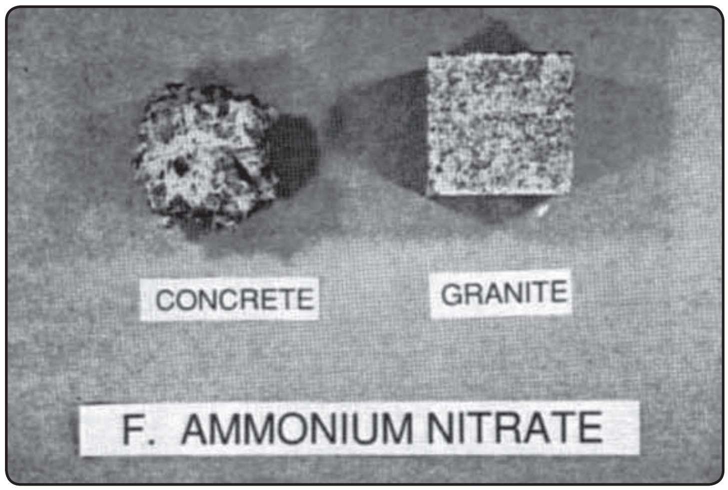

FIGURE 10: Granite and precast PCC samples subjected to immersion testing.