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# **Experimental Evaluation of a Keyed Concrete Curb**

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<b>16. Abstract</b> This report describes the procedures, problems, and costs of installation of a keyway type curb on a new asphalt roadway. The cost of keyed concrete curb is compared to the cost of standard type 2 concrete curb and gutter. Recommendations are made concerning the use of keyed concrete curb on various types of projects.			
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KEYWAY CURB

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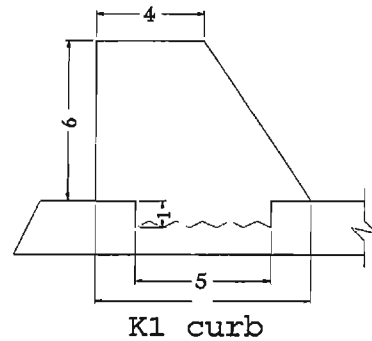
## I. Background

Keyed curbs are tied to the pavement by a key formed when the concrete curb is slip formed over a groove or "keyway" that has been milled into the surface of the pavement. The keyway is a shallow groove 1" to 2" deep and about 5" wide that is cut into the surface of the pavement.

After the keyway is milled into the surface of the pavement, a small machine is used to slip form a curb which is 10" wide at the bottom and 6" high on the surface of the pavement roughly centered over the keyway.

In an advertising brochure Key Way Curb Company lists the following advantages for the use of keyed curbs:

- A contractor can expect installation of at least 3000' per day (more under ideal conditions)
  - Cost savings, in a retro-fit, of 40% to 50% over conventional curb and gutter.
  - There is no vertical joint between the gutter pan and the asphalt of the pavement.
- Elimination of this joint removes a major area where water penetrates below the pavement.



**Keyway milling machine**

## II. Installation

Project NH-FC-STE(CX) 024-3(32) was constructed in Colorado Springs in 1993. It included 1316 feet of keyed curb installed in the median on US 24 just east of the interchange with Circle Dr. Installation was done by the Key Way Curb Company of Colorado Springs.

Approximately 1/3 of the curb is on the median side of westbound US 24 and the remainder is on the median side eastbound. The curb is straight through most of its length with a gentle curve near the east end and tightly curved sections (radius of less than ten feet) where it crosses the median at the west end. All of the curb through the straight sections, the sharp curves through the median, and the gentle curves along the highway is very smooth and well formed.

The keyway milling machine used on this project looked and operated something like a large rototiller. In place of the tilling blades the machine had a wheel about 18" in

diameter with 12 conical carbide teeth like the ones on large pavement milling machines spaced around the rim. The teeth are mounted at varying angles to the plane of the wheel so they actually cut three grooves which overlap to form the keyway.



**Short radius curve through the median**

The slip form machine, which was about the size of a golf cart, is made up of a hopper, a small gasoline engine, a horizontal auger, and slip form. The engine turns the auger which is in the front end of the slip form. As it pushes the concrete into and through the form it also pushes the machine forward. This simple arrangement assures that the curb is solid and without voids since the machine doesn't move unless the form is completely full. Using a handle like a toy wagon, the operator guided the machine following lines chalked on the pavement. By laying the lines out from the shoulder stripe, the crew was able to form the curb into a smooth curve that resulted in a very uniform shoulder. Since the machine is fairly small it is easy to follow straight and gentle curves along the roadway or make tight curves where they are needed.



**The Curb slip form machine**

Since it is not possible to put any reinforcement into the curb because of the way it is formed, reinforcing fibers are added to the mix at the plant to make the concrete stronger. There is no side walk or fill behind the curb to add support; it relies completely on the concrete and the keyed joint with the pavement for its strength.

### **A. Milling the Keyway**

The plans called for a keyway one inch deep by three inches wide for this project. Getting the keyway cut to a depth of one inch proved to be difficult. The operator complained of unexpected hardness in the asphalt due to the cold weather. The fact that the milling machine was relatively light and used large conical teeth designed for huge pavement milling operations may have contributed to the difficulty also. After multiple passes the operator managed to achieve a usable depth. However, the finished keyway was not a square cornered, flat bottomed channel with vertical sides as shown in the drawings; It was more of a wide groove with sloping sides, rounded corners, and a rough bottom.



**Milling machine wheel and teeth**

The project engineer was concerned about the shape and depth of the keyway and its effects on the strength of the final product, however, he agreed to accept the keyway at a depth of 3/4 inch. During the three year evaluation of the curb, there has been no indication that the shape or depth of the keyway has had any detrimental effect on the function of the curb.

Figures 1&2, from the Keyway Curb Company's brochure, show the original model K1 curb with the new wider five inch key and a new K2 model curb which is designed to have asphalt placed to the level of a narrow concrete par which is slip cast with the curb.

## **B. Pouring the Curb**

The slip form for the curb has a hopper to receive the concrete from the mixer truck, an auger which pushes the concrete from the hopper into the form, and a small gasoline engine to drive the auger. By pushing the concrete through the slip form, the auger drives the machine forward. This method insures a good curb with no voids because the machine does not move unless there is sufficient mix in the hopper for the auger to be able to pack the form completely. The operator follows a chalked line laid out from the shoulder stripe steering with a handle similar to a toy wagon. The finished curb is very even with smooth curves.



Laying out the Guide lines

The east end of the keyed curb is installed is on a gentle curve. In this area the chalked reference line was made up of chords about 12' long. Figure 6 shows the smooth



curve of the finished curb. The straight sections at the west end of the project were smooth and straight.

### III. Costs

The tabulation of bids for this project from Lawrence Construction listed the price of type 2 II-M curb and gutter at \$8.50 per linear foot, keyed curb at \$18.00 per foot for 812 feet originally in the project and \$5.28 per foot for 504 feet added later. The high price for the original section was possibly because they were inexperienced with the keyed curb and felt that it was necessary to price it high to cover possible problems. (An interesting note: The Keyway Curb Company, which did the actual installation using its own people and equipment, charged \$4.25 per foot for this job. Bill Harger, the owner of Keyway Curb Company, has set a



**Type 2 curb and gutter meets type K1 keyed curb just beyond the sign post**

maximum price to CDOT as of January, 1997 of \$6.50 per foot, and said that most jobs will cost less.)

Because prices vary for all of the components of a job it is difficult to say whether a Keyed curb is more or less expensive than a standard type II-M curb on new construction. A direct comparison of \$8.50 per foot for type 2 II-M curb and gutter to \$5.28 per foot for the final section of keyed curb is misleading. To use a keyed curb instead of a type 2 curb and

gutter, it is necessary to increase the width of the asphalt pavement by 36". The extra width replaces the 24" pan of the type 2 and provides the necessary 10" for the curb and 2" behind for support so the curb isn't sitting right on the edge of the asphalt. Assuming a thickness of 6" for the asphalt, and using the prices quoted for this job of \$21.90/ton and \$30.40/ton for asphalt, the extra asphalt would cost \$2.75<sub>1</sub> per linear foot of curb. Adding the cost of the extra asphalt to the bid price of the curb gives an actual cost of \$8.03 per linear foot for keyed curb on this project.

#### IV. Questions and Points of Concern

Some questions and concerns voiced about the use of keyed curbs:

Q. Will the curb break and/or be pushed out of position by snow plows and being hit by traffic?

A. In three years since its installation there is evidence that the curb has been hit by snow plows and by vehicles that went over it and into the median. The curb face is marked particularly on the eastbound sections where it is on the outside of a curve. It appears to have been gouged by plow blades and hit and ridden over by vehicles that went into the median and then back over the curb to get back onto the highway. From tire marks in the median it is apparent that at least some of the vehicles that have gone over the curb were trucks with dual wheels. There is no indication that any of the incidents caused any more than superficial damage to the curb. The curb face and top is scratched and gouged but the curb is not broken or structurally damaged. None of the curb has cracked nor has it loosened at the joint with the pavement. It is important to note that the curb on this job is completely unsupported from behind. Its strength comes from the strength of the fiber reinforced concrete and the key which locks it to the asphalt.

Q. Freeze - thaw cycles are responsible for a large portion of the damage done to pavements and appurtenances. Since there is a continuous joint along both sides of the base of the curb there will be moisture penetration under the curb. During the winter will water get under the curb and freeze causing it to lift out of the keyway?

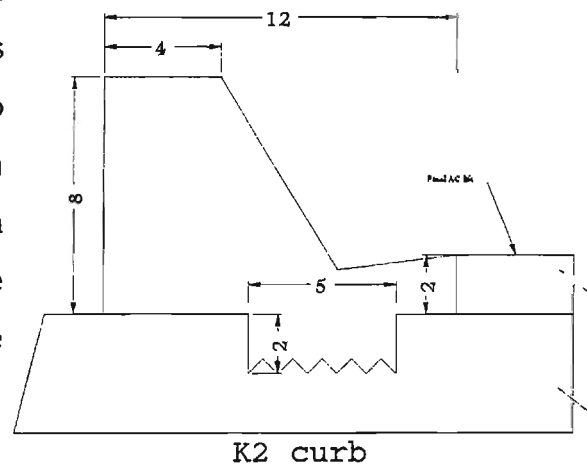
A. There is no evidence of the curb lifting out of the keyway. (Melting snow in the median drained against the back of the curb along its entire length.)

Q. Will the shape of the keyway have an effect on the durability of the curb?

A. There were no failures of the curb during the evaluation so it is only possible to say that the shape of the keyway has not caused any problems yet.

Q. This type of design cannot carry as much water as a standard type II design. Since the curb is placed on the surface of the pavement, there is no area of increased slope next to the curb to control running water like the pan on a type 2 curb and gutter.

A. This is a characteristic of the design. In areas that handle large volumes of water the keyed curb design used on this project is probably not the best choice. Keyway Curb Company does, however, have a new design called the K2 model. This new shape incorporates a concrete pan below the curb. It is designed to be installed on a lower lift of pavement and then matched with a 2" final lift. It does not provide a pan as wide as a type 2 design, but does provide for increased water handling capacity over the original K1 model.



## V. Conclusions

As of January of 1997, the CDOT has a design detail for using the key way curb as an alternative to standard methods and is considering revising the M-Standards to include the keyed method for retro-fitting curbs on existing pavement.

There are advantages to using a keyed curb in some situations: For a retro-fit project in areas of existing pavement where there has not been a curb before, the keyed curb is especially attractive. It is faster than "conventional designs" and involves less disruption of traffic and exposes crews to the dangers of working near traffic for shorter periods of time. The keyway can be cut and the curb slip formed very rapidly. It can be a cost effective option in a retro-fit situation for these reasons.

In rural situations it may be possible to install a keyed curb under an existing guard rail to provide control of water flow off the side of the road surface. This reduces both time and labor costs and inconvenience to the public. (This was done on a section of I 25 near Raton Pass.)

Since a keyed curb sits on the surface of the pavement it does not provide a vertical joint where water can get below the pavement to cause problems. This could be an advantage in areas with poor drainage on the surface of the pavement.

A keyed curb is probably not the best option in an area where the curb and gutter must handle a large quantity of water. Since the curb sits directly on the surface of the pavement, there is no gutter pan with a steeper angle to contain water. A given volume of water flowing along a keyed curb will extend farther onto the pavement surface than the same volume contained in the deeper gutter of a type II design.

Retro-fitting a keyed curb reduces the usable width of the pavement by about 10 inches; the curb itself takes up 8 inches and about 2 inches is taken by the setback from the edge of the pavement.

Keyed curbs are an option worth considering. The most effective use for a keyed curb is on an existing pavement. In a situation where a curb is to be installed along the edge of a shoulder to divert water to a drain rather than have it run off the surface eroding the bank, a keyed concrete curb is possibly the fastest, most convenient and most cost effective option.

## V. Endnotes

The cost comparisons used in this study were based on the costs of materials used on this project.

This cost for asphalt was figured by: 1. assuming asphalt is two tons per cubic yard. 2. using the contractor's bid prices of \$21.90/ton and \$30.40/ton for HBP Gr C and Gr CX respectively 3. using a ratio of 2:1 for the quantities of HBP Gr C and Gr CX since the Tabulation of bids shows that ratio for total quantities. 4. assuming that the asphalt to replace the pan part of a type 2 II-M curb and gutter would be 6" thick and 36" wide or 1.5 cubic feet.

$$(\$21.90 \times 2 + \$30.40)/3 \times 2 = \$49.47/\text{cu. yd.} = \$1.83/\text{cu. ft. cost of asphalt}$$

$(36" \times 6" \times 12")/1728 = 1.5 \text{ cu. ft. of asphalt to replace the bottom part of the curb and gutter.}$

$$1.5 \text{ cu. ft. @ } \$1.83/\text{cu ft} = \$2.75/\text{linear ft of asphalt}$$

$\$2.75 \text{ for asphalt} + \$5.28 \text{ for keyed curb} = \$8.03 \text{ cost per foot to replace type 2 II-M curb and gutter with keyed curb.}$