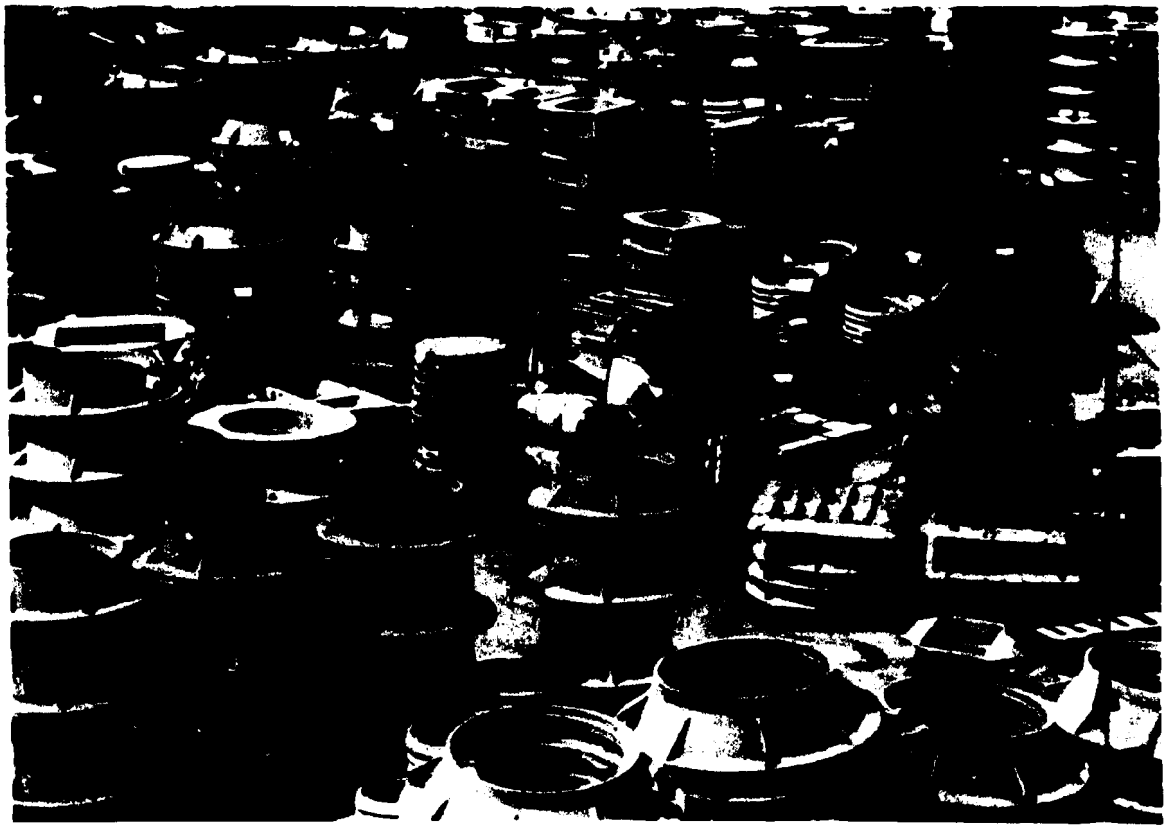
Publication No. FHWA-TS-90-040
August 1990
Materials and Operations

Value Engineering Study of Curbs and Drainage



U.S. Department of Transportation
Federal Highway Administration

Office of Implementation
Research, Development, and Technology
Turner-Fairbank Highway Research Center
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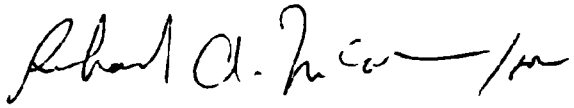
McLean, Virginia 22101-2296

FOREWORD

This Tech Share report summarizes the results of a cooperative Value Engineering Study of Curbs and Drainage. The study was conducted by the States of Michigan, Minnesota, West Virginia, and Wisconsin. The report should be of interest to State and local maintenance and design engineers concerned with the proper methods of curb placement and drainage.

Research, development and implementation for improving maintenance operations is included in the Nationally Coordinated Program (NCP) of Highway Research, Development, and Technology (RD&T) in Category E, Materials and Operations; Program Area E.5, Highway Maintenance.



Office of Implementation

NOTICE

Technical Report Documentation Page

1. Report No.	2.	3. Recipient's Catalog No.
FHWA-TS-90-040	PB91-238220	

4. Title and Subtitle	5. Report Date
Value Engineering Study of Curbs and Drainage	August 1990
	6. Performing Organization Code
7. Author's	8. Performing Organization Report No.
James W. Hudson, CVS	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
James W. Hudson and Associates P.O. Box 399 Spotsylvania, VA 22553	3E9E0053
	11. Contract or Grant No.
	DTFH61-86-C-00734
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	FINAL
Federal Highway Administration Office of Implementation (HRT-10) 6300 Georgetown Pike McLean, Virginia 22101	14. Sponsoring Agency Code

15. Supplementary Notes

FHWA COTR: John Wasley, HRT-10

16. Abstract

A Value Engineering Study was performed by four State highway agencies; Michigan, Minnesota, West Virginia, and Wisconsin, covering various aspects of curbs, drainage structures, drainage castings, and gutters. Twenty seven specific proposals are given for the consideration of highway agencies. To add credibility, a draft report was circulated to the members of the AASHTO Task Force on Hydraulics and Hydrology. Some of the proposals are: minimize cover over pipes, broaden specifications and standards, air entrained concrete, inlet frames with inward protruding flanges, high efficiency grates, eliminate ribs on manhole covers, eliminate adjustable manhole frames, minimize curb drainage, creative uses for slotted vane grates, provide designers with relative costs, reduce the number of standard grates, eliminate metal frames from concrete inlet boxes, standardize design of curbs and gutters, have only six standard curbs and gutters, minimize thickness of gutter pans, eliminate reinforcement in curbs and gutters, specify batter, minimize tight specifications, increase hydraulic capacity of gutters, use curbs to minimize right of way, and avoid oversized drainage inlets.

17. Key Words	18. Distribution Statement
Value Engineering, Curbs, Gutters, Drainage, Inlets, Inlet Grates, Slotted Drains, Design Standards, Manholes, Drainage Structures, Curb Openings	No restrictions. This document is available from the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	48	

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SI* (MODERN METRIC) CONVERSION FACTORS

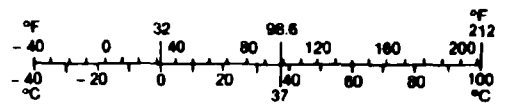
APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
AREA				
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
VOLUME				
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
TEMPERATURE (exact)				
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

NOTE: Volumes greater than 1000 L shall be shown in m^3.

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
AREA				
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
VOLUME				
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
TEMPERATURE (exact)				
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



* SI is the symbol for the International System of Measurement

(Revised April 1989)

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VALUE ENGINEERING STUDY

HIGHWAY CURBING AND DRAINAGE

Background

Highway construction and maintenance standards often times have been derived from historical data and/or subjective evaluations completed by committees of experienced highway personnel. Also, those States that have developed standards usually have done so independently. As a result, many construction and maintenance activities do not utilize the optimum available materials, equipment or labor. In particular the standardization of some construction items on a regional basis could provide for greater bidding competition by contractors, resulting from lower costs charged by suppliers and also would simplify the preparation required for certain bid items. But of more importance, the standardization of design specifications and construction methods for various highway contract items could yield substantial savings to a State highway agency when projected over a high production volume that would result from the total number of projects that are annually awarded for construction. Also, the standardization could have a positive general cost saving effect on future maintenance. For example, this could occur because the number of repair parts needed to be kept on inventory would be reduced and possibly a repair that was needed would be simplified or even eliminated.

On a regional basis, adjacent States often use the same contractors. By standardizing construction details and specifications, final construction costs could be reduced. Also, on a regional basis there are many construction activities that would lend themselves to standardization. Two construction activities that stand out in particular construction of curbing and drainage (i.e., inlets and outlets) items. The design and construction methods of these activities have varied greatly among States. If differences such as materials used and design specifications could be studied concerning standardization, cost benefits would be substantial.

Value Engineering is a process of analysis that uses a team approach to solving problems by investigating the basic "Functions" of a procedure, product, hardware item, etc. The purpose is to ascertain a performance feature that must be obtained and then through "Creative" techniques, such as brainstorming and "Premise Plateau," alternatives are sought that satisfy the function in a more cost effective manner.

After identifying the basic functions, a determination is made of its "Worth." Worth is the least expensive way in which the function may be performed. Then an estimate is made of the cost of satisfying the function and compared with the worth. A high cost to worth ratio suggests a high potential for cost savings can be realized.

The Creative Phase identifies many alternatives, by applying necessary criteria, standards, reasonable specifications, etc., unacceptable alternatives are eliminated. The remaining alternatives are costed and the best solutions developed as VE change proposals. These are properly documented in a report format of some type and presented for approval and adoption by the appropriate management officials. Following approval, including any farther conditions the approving officials may have made, the VE change proposals are then implemented.

This report summarizes the results and recommended VE change proposals from a cooperative VE study. The study was completed on the possible regional standardization of both design standards/features and construction methods/practices for highway curbing and drainage construction items. This study was performed under the sponsorship of the Federal Highway Administration (FHWA) Office of Implementation by VE study teams selected from the State highway agencies of Michigan, Minnesota and Wisconsin in FHWA Region 5 and West Virginia in FHWA Region 3. Also, considered were the probable results and savings that may occur to the future total maintenance required if the recommended VE change proposals were implemented. The original study was completed in 1984 and was updated in 1987. The update considered changes that evolved in design and construction standards, methods and materials, such as the greater availability and use of precast concrete drainage items. Also new labor saving types of equipment now used for construction and maintenance activities were considered.

The findings and VE change proposals documented in this report were based on a consensus of the VE study team members from the four participating States. They relate most specifically to design standards, construction methods and maintenance procedures used by those States.

The study results do not necessarily reflect recommendations of the Federal Highway Administration.

Also, this report is written for use mainly by practioners familiar with highway design, construction and maintenance. A basic understanding of the problems, procedures and methods used in curbing and highway drainage, construction and maintenance were assumed.

Project Objectives

The major objective of this study was to optimize expenditure of construction and maintenance resources by an in-depth VE analysis of curbing and drainage construction activities.

A. DRAINAGE STRUCTURES:

A1: The function of inlets and catch basins is to collect runoff. Their size and spacing depend primarily on this function, although maintenance requirements and ability to accommodate intersecting drains may also influence this sizing.

With newer maintenance techniques, such as vacuuming and jetting available, the need for oversizing solely on the basis of accommodating manual cleanout, is no longer valid.

Also, saddles and stubs may be used to reduce the problem of sizing for the accommodation of intersecting pipes within the walls of the drainage structure.

In summary, the cross section of the drainage structure should be sized to provide the required hydraulic capacity using current design techniques and maintenance procedures. Oftentimes, drainage items are oversized on the basis of past practice and not good sound engineering principles.

A2: VE PROPOSAL: ELIMINATE SUMPS IN DRAINAGE STRUCTURES:

Many agencies use sumps as a receptacle of debris borne by runoff. Some of these have found it impractical to provide periodic cleanout. Unless such periodic cleanout is provided, these sumps no longer function as intended, possibly causing foul odors and a health hazard, and their benefit is questionable.

Under these circumstances, construction and maintenance costs may be reduced by the elimination of sumps.

This agrees with the recommendation of ASCE 37, Manual of Engineering Practices, Design of Sanitary and Storm Sewers.

A3: VE PROPOSAL: MINIMIZE THE COVER OVER PIPES:

Pipe depths are generally controlled by hydraulic design, depth of cover to accommodate wheel loads and depth of frost penetration. Several Northern States have found that reducing cover to as little as two feet (60 cm) has resulted in no freezing problem.

Therefore, reducing pipe cover to only that required for structural support and hydraulic capacity without standing water, is recommended.

A4: VE PROPOSAL: TO BROADEN SPECIFICATIONS AND STANDARDS FOR DRAINAGE STRUCTURES AS MUCH AS POSSIBLE TO ENCOURAGE COMPETITION:

Specifications and standards for drainage structures

may have evolved from one prototype. They may be highly restrictive and virtually proprietary, such as calling for a round shape and thus eliminating rectangular and other cross sections from consideration.

A performance type specification can give the critical dimensions to accomplish the hydraulic, structural, and maintenance functions. Effort should be taken not to tie down the precise shape. Thus inviting additional competition from those capable of supplying other shape structures that will perform the desired functions equally well.

Broad or performance type specifications inspire innovation by suppliers. Their manufacturing methods may favor one shape over another, and enable them to quote lower prices.

Firms that have supplied an agency a certain product for some time are induced to reconsider their prices when they see the broader interpretation that might encourage new suppliers to bid, therefore another benefit of broader specifications.

Some agencies have opened their specifications to encourage competition. Two examples are given in Figures 1 and 2.

A5: VE PROPOSAL: USE AIR ENTRAINED CONCRETE FOR GROUT:

Air entrained concrete should be used wherever grout is needed, such as in the construction of spacers between the drainage structure and the surface grate.

The use of air entrained concrete is an effective way to minimize maintenance due to cracking and spalling.

B. GRATES AND COVERS:

B1: VE PROPOSAL: DESIGN INLET FRAME CASTINGS WITHOUT OUTWARD PROTRUSIONS:

Inlet frame castings should be designed without outwardly protruding flanges so that they fit entirely within the curb and gutter. The intent is to select the inlet frame castings that do not interfere with slip form pavers.

Wisconsin DOT, in consultation with contractors, estimates annual labor cost savings of $9,000 could be

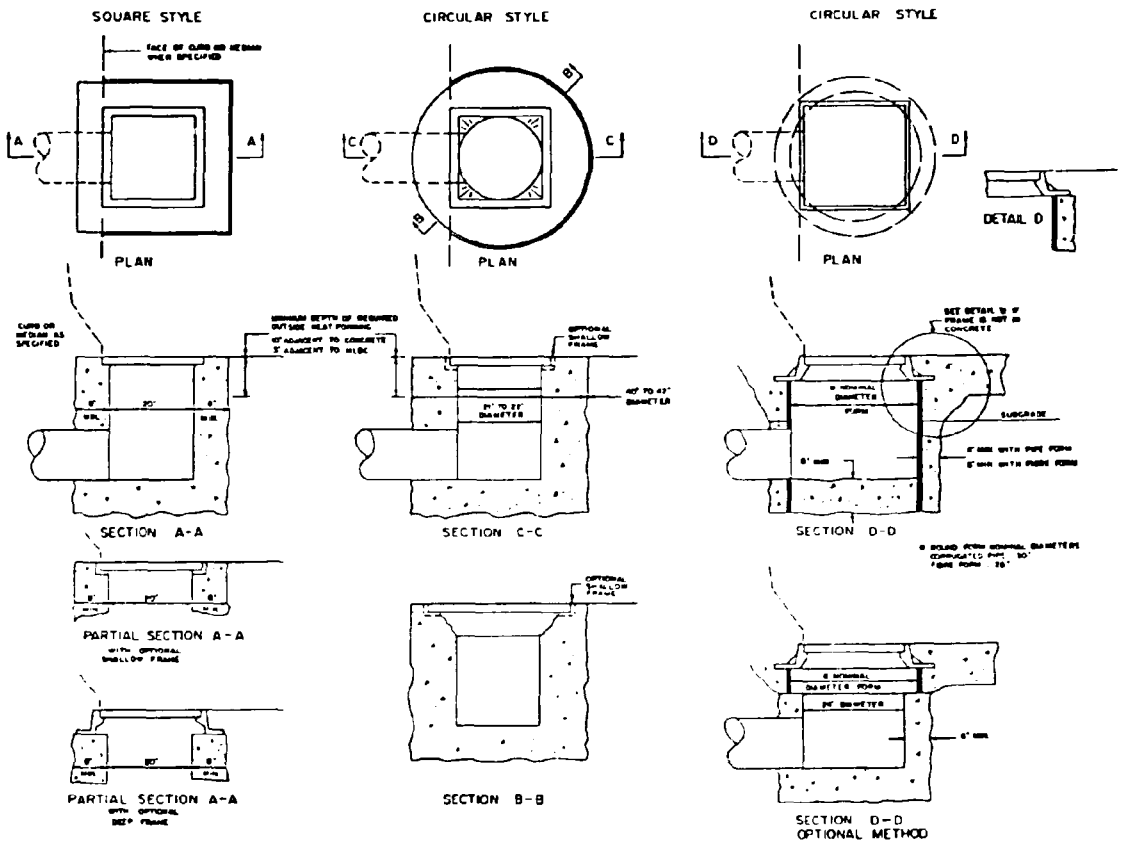


Figure 1

Typical standard of West Virginia Department of Highway Standard Plans.

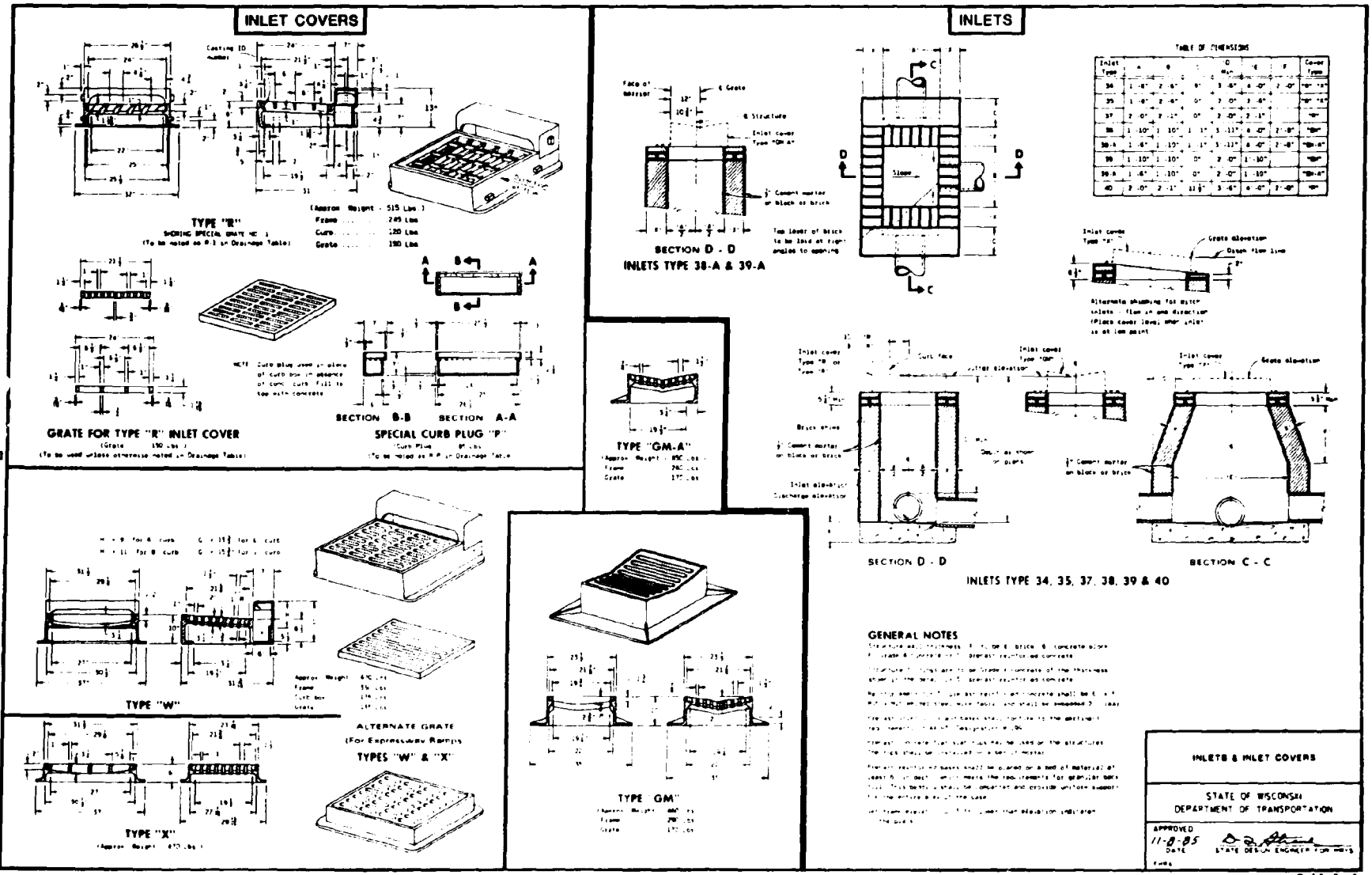


Figure 2

realized if castings did not interfere with slip form pavers in order to keep that operation as continuous as possible. Hand forming methods are required to complete typical ten foot gaps in curb and gutter that must be made to accommodate later placement of the frame casting when slip form paving methods are employed.

Examples of undesirable types are given in Figure 3.

Examples of recommended types are shown in Figure 4.

B2: VE PROPOSAL: USE HIGH EFFICIENCY GRATES:

High efficiency grates, such as tilt bar or vane grates, minimize the number of drainage castings required, particularly on steep grades. These grates must be oriented so the sloping vanes are tilted toward the oncoming flow. When so positioned they deflect flow down through the grate. In sags the effectiveness of a grate is dependent on the total area of openings. Uniformity may control. (figure 5)

West Virginia was able to save about $40,000 annually by changing from typical slotted or straight bar grates to vane grates. This allowed them to increase spacing between drainage structures without reducing drainage capability.

Also, the acceptable spread of flow must be considered in inlet spacing, however, the simplest way to reduce cost of grates is to reduce the quantity required. The designer, when aware of cost differentials, can select and space the inlets efficiently and achieve maximum cost effectiveness.

B3: VE PROPOSAL: TO ELIMINATE THE RIBS ON MANHOLE LIDS:

For many years manhole lids have been supplied with ribs on their bottom surface. The ribs appear to strengthen it but recent research has found this to be untrue. (Fig. 6)

Actual tests show that a platen type lid of the same thickness as the standard rib type has a load capacity 30% greater. The platen lid weighs 10% less and has an impact resistance 400% greater than the old standard with ribs. The simplicity of the platen lid and its reduced weight to accomplish the same function, result in 10% cost savings.

Inventories of the ribbed lids exist and should be worked off by allowing the use of either type. In a short time, the cost differential will eradicate the older, less efficient ribbed lids. Figure 7 shows the platen lid.

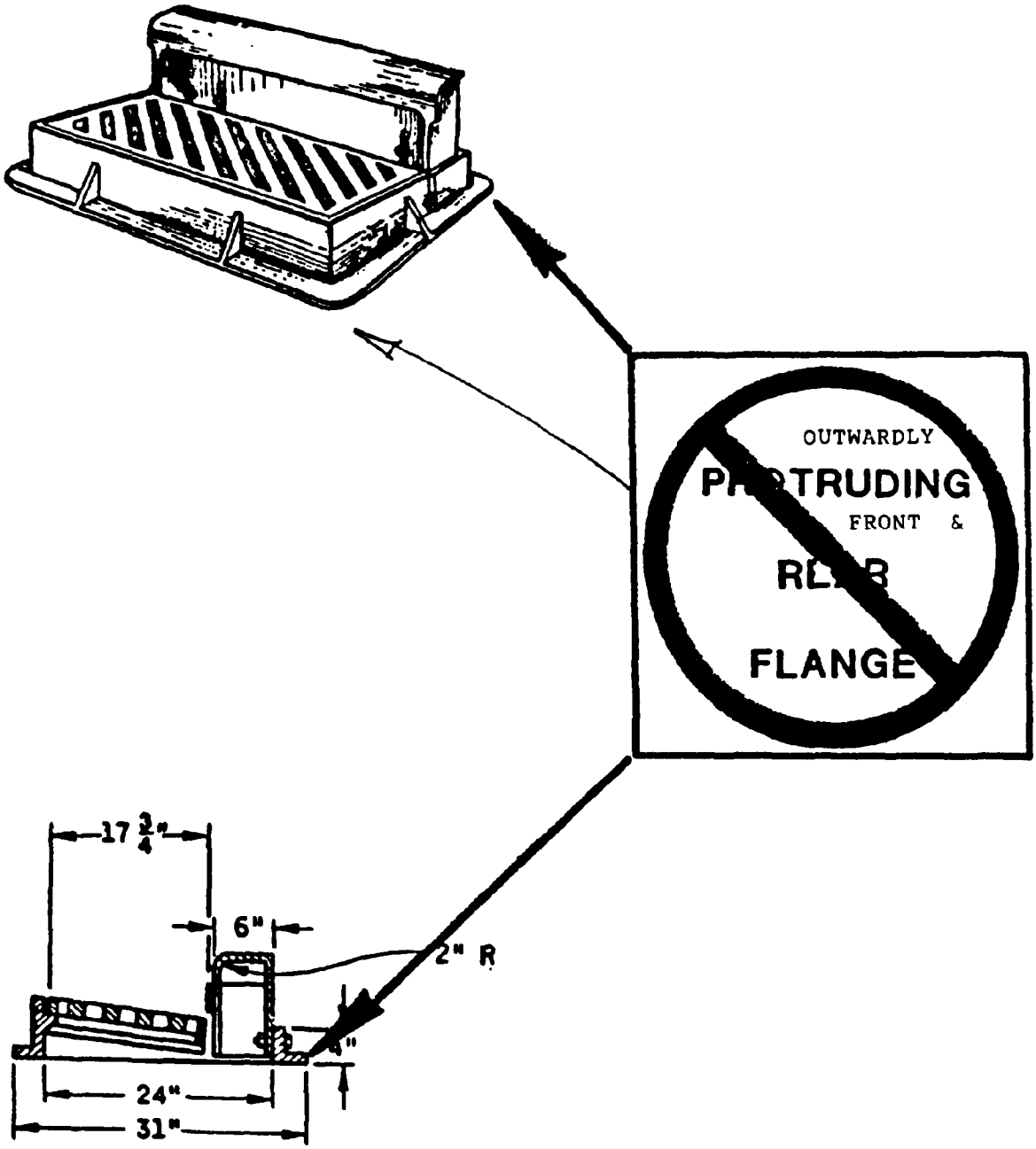
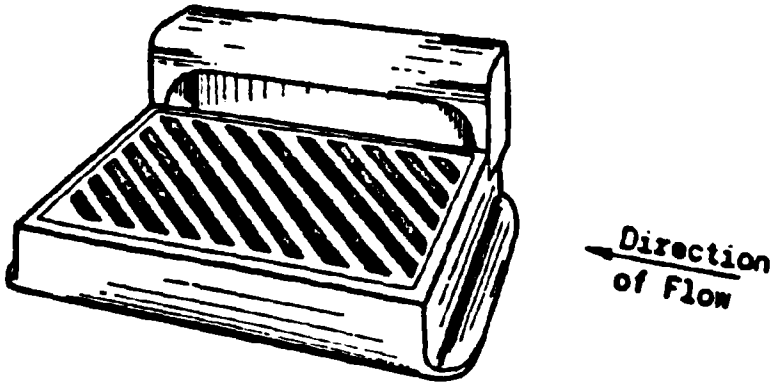


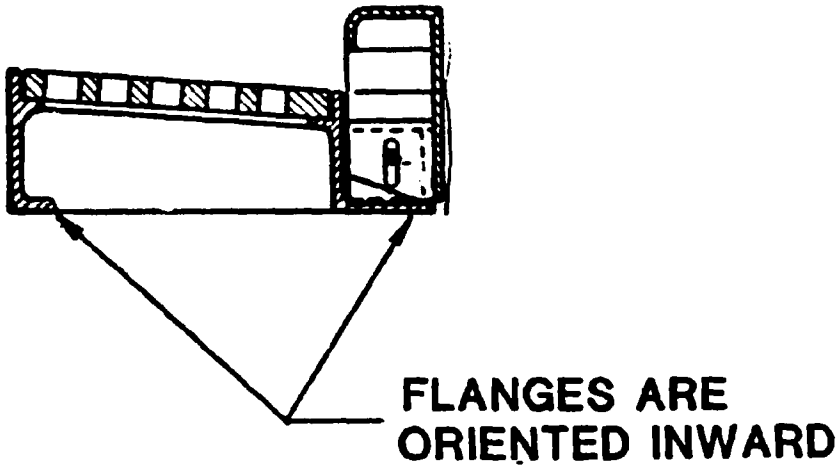
Figure 3

VE Proposal B1 recommends the elimination of front and rear outwardly extending protrusions.

Source the Wisconsin Department of Highways.



TYPE "WM"

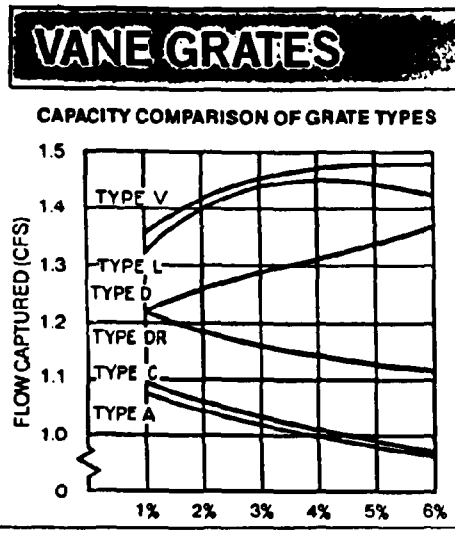


DRAINAGE CASTING WITH INTERNAL FLANGES

Figure 4

Recommended Flange Orientation

Source: Wisconsin Department of Transportation



Cross Section of Vane Grate in Testing Flume Showing Performance at 2 cfs.

The chart shows flume tests conducted by the Neenah Foundry to compare various types of grates.

The primary function of an inlet grate is capacity to intercept storm water from a gutter. These tests indicated that vane grates were as much as 20% more efficient than conventional designs. A properly functioning inlet grate should screen out large items of debris that might clog the sewer pipes and permit the passage of smaller stones, etc. that can be passed by the underground parts of the drainage system. These vaned grates can be sized to accomplish the proper screening of debris.
When the vanes are perpendicular to the curb line they are as bicycle safe as similar conventional grates.
The various grate types used in the tests are shown below.

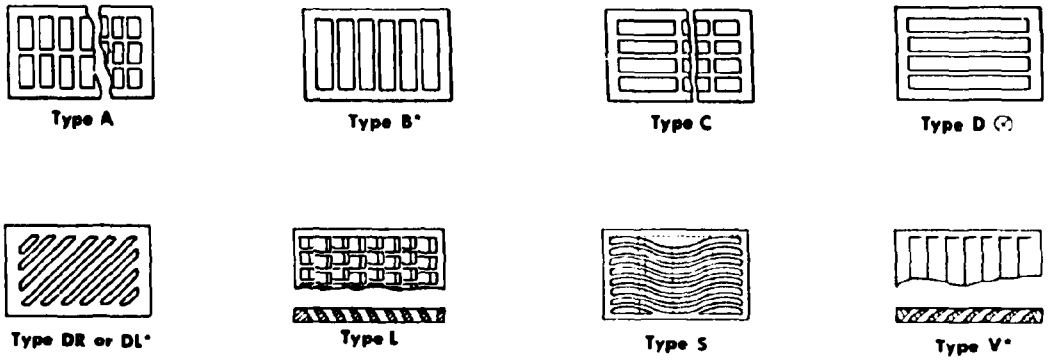
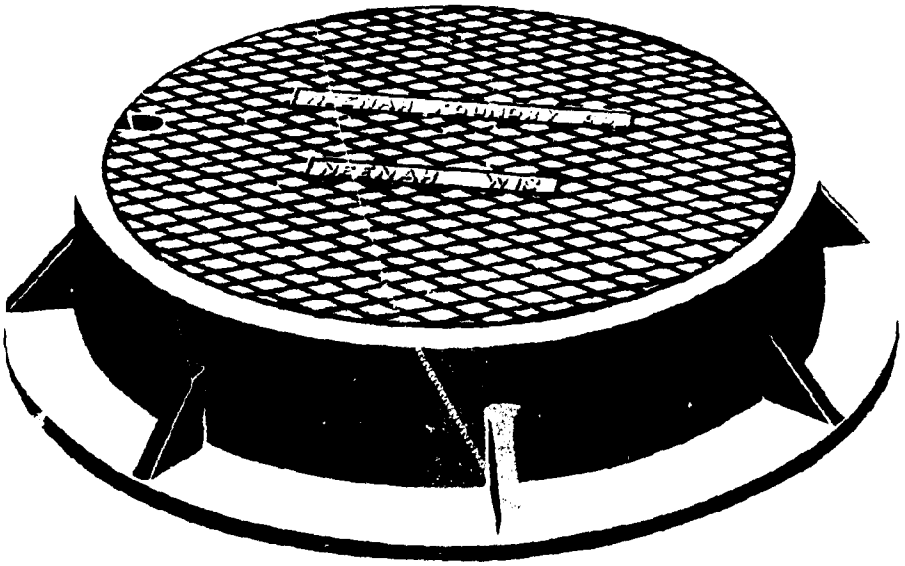


Figure 5

Flume test data for various grate types

Source: Neenah Foundry Co.; Wisconsin



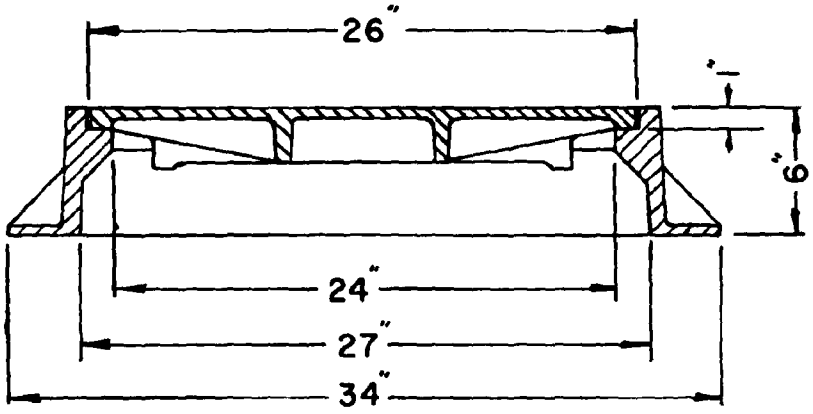
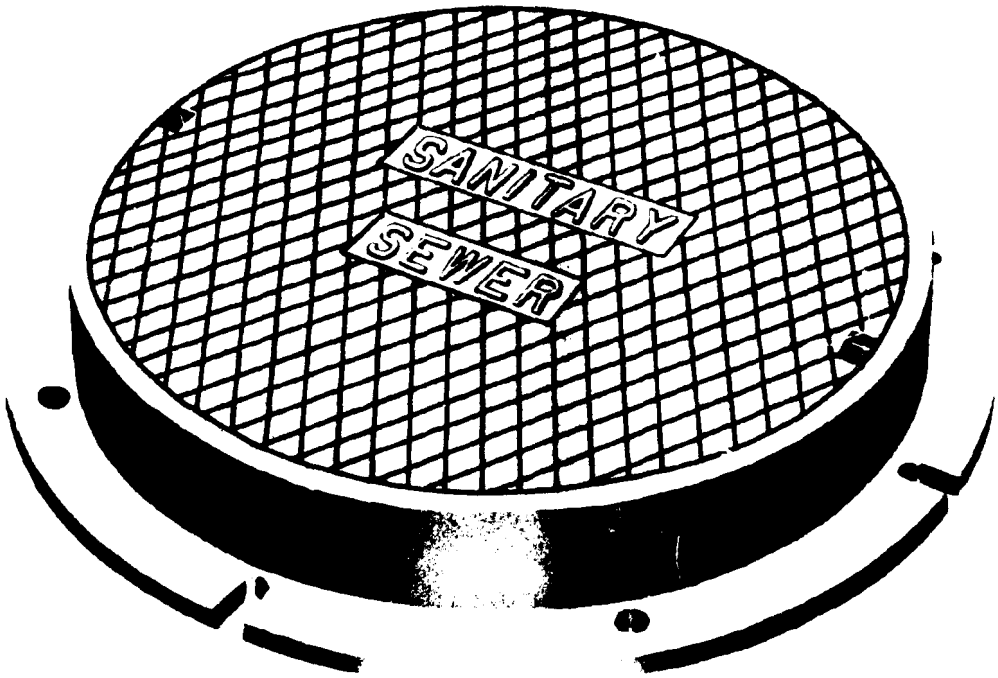


Figure 6
Manhole Cover with Reinforcing Ribs
Source: Neenah Foundry Co., Wisconsin



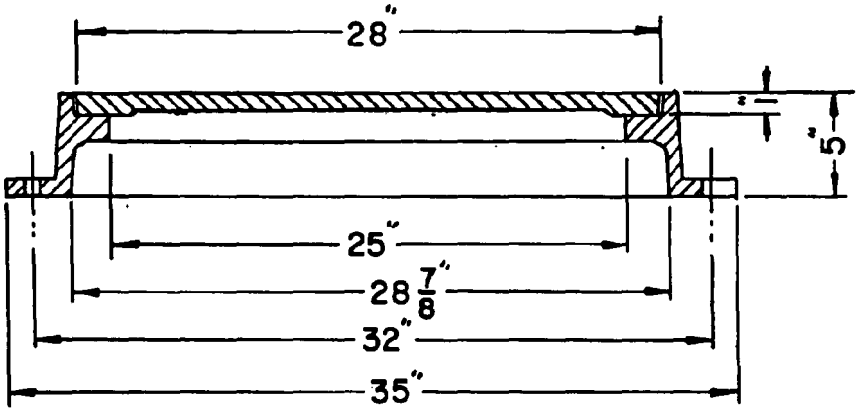


Figure 7
Flat Platen Manhole Cover
Source: Neenah Foundry Co., Wisconsin

B4: VE PROPOSAL: TO ELIMINATE ADJUSTABLE MANHOLE FRAMES:

Adjustable frames are sometimes provided to allow the raising of manhole covers after the resurfacing of the Pavement. The bolts used to make this adjustment are rarely operable when the time comes to raise the covers. However, since the rings are provided, the crew may feel obliged to make them work and much time can be lost in the process. Figure 8 shows such an adjustable frame.

The elimination of the adjustable frames reduces the cost of the casting and the cost of maintenance.

B5: VE PROPOSAL: TO OPTIMIZE THE USE OF CURB DRAINAGE:

Curb openings are not as effective as grates on steep grades as much of the flow will bypass the openings unless they are elongated. Even on grade, however, they may be warranted in combination with grates to maximize total efficiency and permit materials to enter the system that are too coarse to pass through the grates.

The team compared costs and found curb openings without grates to be $1,300 to $1,600 more costly than grate inlets providing the same inlet capacity.

The added cost to provide curb openings may be justified in certain instances, such as where there are narrow gutters and lanes. A grate of adequate size installed in these conditions might protrude into the traffic lane where it would be subjected to damaging wheel loads and impacts.

In sags, curb openings are effective in removing runoff either alone or in combination with grates.

B6: VE PROPOSAL: TO CREATIVELY USE SLOTTED VANE DRAINS:

Slotted vane drains can be effective under many circumstances. On grades they can be used to supplement the capacity of grates by collecting the flow extending into the roadway that may otherwise bypass the grate. The spacing between inlets may thus be increased and total construction costs reduced.

Slotted vane drains extending into the shoulder can be readily exposed by snow plows and thereby provide a drainage safety factor to prevent ponding in northern climates where grates located in the gutter can become clogged with ice and snow.

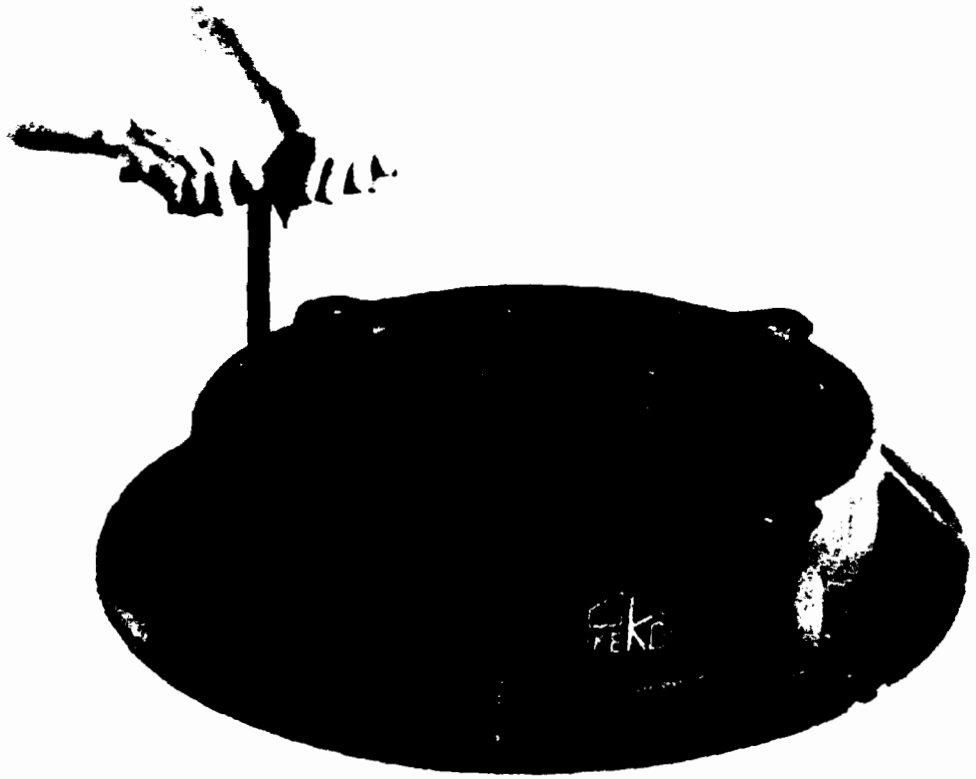


Figure 8: Bolt Adjustable Manhole Cover Not Recommended.

Slotted vane grates can effectively capture sheet flow from a variety of conditions such as parking areas, superelevated curves and ramps, and along curbs or concrete barriers, particularly where alternate freezing and thawing occurs.

Slotted vane drains provide the designer and maintenance engineer with a flexible tool for preventive, corrective and supplemental applications on both new construction and reconstruction projects.

An interesting application of slotted drains was made by the Wisconsin Department of Transportation in 1977 on a stretch of Interstate Highway 94 at the time a concrete median barrier was installed to replace an aluminum box beam median barrier. The concrete median barrier interrupted the normal surface drainage because the median was sloped to a flow line and inlets that were offset 2 feet from the centerline of the median.

Drainage slots were provided under the concrete barrier at the inlet locations, but additional drainage capacity was necessary to collect runoff from the side of the barrier opposite to the flow line. An additional concern in this northern climate is the need to collect frequent runoff from melting ice and snow that accumulates along barrier walls and at times causes ponding onto the traffic lane.

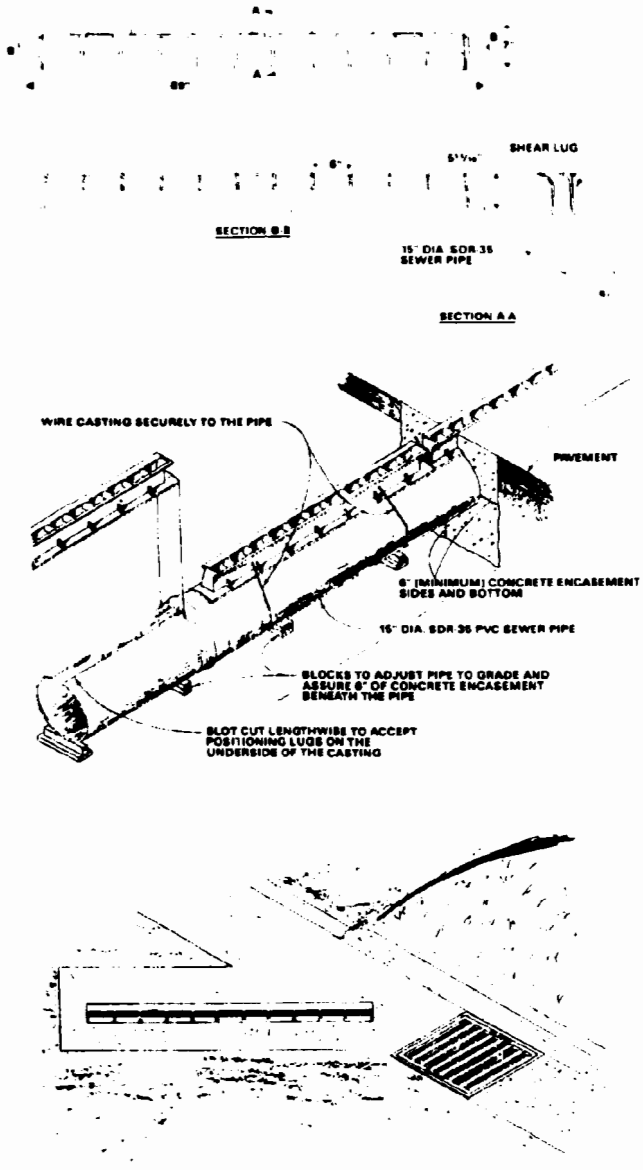
The Wisconsin DOT decided to supplement the existing drainage system with slotted drains connected to the existing inlets rather than by new or expanded grate inlets. The slotted drains were installed across the shoulders at the inlets on both sides of the barrier. The installed cost of each drain was $450, compared with conventional drop inlets installed nearby at $800. After ten years of service these drains have not been a maintenance problem. The surface openings do not clog and the pipes are flushed clean during rainfalls.

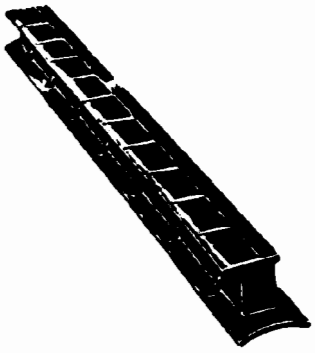
Slotted drains are bicycle safe as described in FHWA-RD-80/081.

The final selection between slotted drains and multiple inlet structures should reflect both economy and safety. Grates within the wheel paths, unless adequately anchored, are a potential safety problem. Slotted drains often can both reduce costs and improve performance.
Figures 9 and 10 illustrate this application.

B7: VE PROPOSAL: TO MAKE RELATIVE COSTS AVAILABLE TO DESIGNERS:

Engineers may select castings and other components of a drainage system that are inherently mare expensive than others that are equally effective for that particular application. For instance, an inlet may have been designed





Cast Iron Slotted Vane Drain offers ease of installation along with the superior vaned configuration to capture previously unexpected quantities of water when placed perpendicular to the flow. Installation is accomplished by sawing a slot in the top of conventional PVC pipe, placing the pipe on grade, installing the Cast Iron Slotted Vane Drain in place and pouring the concrete. Drain is pedestrian and bicycle safe and can be used with confidence in urban areas. When used in conjunction with a vane grate inlet as shown in Figure virtually all of the water in the street which would normally bypass the catch basin can be captured, thus increasing the space between inlets. An additional benefit is the added safety factor obtained should the catch basin be plugged or covered with snow. The unit may also be installed at entrances and exits of parking areas to capture sheet flow before it enters a commercial street.

Figure 9

Concrete Encased Slotted Vane Drain

Source: Neenah Foundry Co., Wisconsin

Water falls into the Slotted Drain's open grate, drops to the corrugated pipe below, and is channeled beneath the concrete barrier to an existing collector line (see drawing).

The 15-inch-diameter (38 cm) pipe was furnished in galvanized steel with helical corrugations. The welded steel slot extends six inches (15 cm) above the top of the pipe.

Economical, too

The Slotted Drain design proved to be relatively economical, too. Installation of each Slotted Drain inlet cost about $450, including the cost of the pipe and fittings. Conventional drop inlets, installed in a related project nearby, were $800. A total of 90 Slotted Drain inlets were installed.

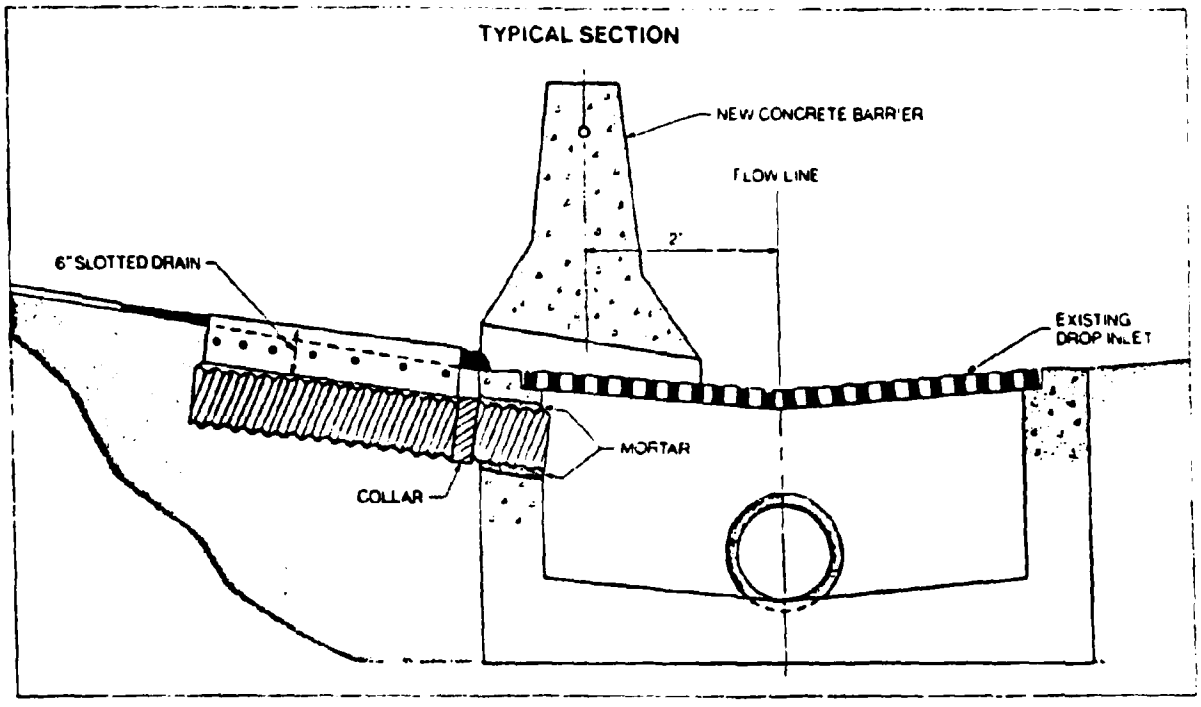


Figure 10: Wisconsin Special Slotted Drain Design

Source: Armco Steel

for high volume, high speed freeways where even temporary clogging of the grates can be hazardous, but for another application the higher cost of such an inlet may not be warranted.

For example, in West Virginia they use a grate they identify as Type H that was designed for high traffic. They are about twice as expensive as their Type B inlets that function satisfactorily for most conditions. If designers are made aware of the relative costs and hydraulic effectiveness of the units they specify, they can produce more cost effective drainage systems.

A review of inlets awarded in 1983 in the State of West Virginia revealed that inlet costs are probably regarded as insignificant when inlet types are selected. The Table 1 below shows some substantial savings that could have been realized by selection of alternate inlet types that would have adequately provided the necessary drainage:

TABLE 1: CONSTRUCTION Contract Award Information*

INLETS AWARDED IN 1983			ALTERNATE INLETS		ANNUAL SAVING
NUMBER	TYPE	COST	TYPE	COST	$
137	H	$2850	B	$1159	$232,000
17	D	$2459	B	$1159	$ 22,000
40	E	$2135	B	$1159	$ 39,000
		TOTAL POTENTIAL ANNUAL SAVING			$293,000

*Source: West Virginia Department of Highways

There are several ways that can be used to make cost data available to designers. One is to make in-house tabulations of recent bid and contract data that can be referred to and better understand relative costs. Rarely is it necessary to have exact cost.

Another way is similar to that used by many industrial engineers, called Standard Costs. These are baseline costs that represented comparative costs when compiled but over time may not represent actual costs, but they are useful in making selection for they give the relative costs of the castings or other components listed. In this way the designer can design a drainage system based on hydraulics and be conscious of the cost implications.

Standard Costs are used to make economic comparisons between functional equivalents. It is an index for use by

the designer to optimize selection on a generic basis rather than by brand name.

All government agencies are more aware of the necessity of making cost effective decisions. It is imperative that highway agencies use procedures such as this to inculcate cost consciousness in all aspects of contracting.

Figure 11 illustrates one way Wisconsin DOT make their designers aware of cost differentials. The relative weights of the castings are usually a direct reflection of the cost.

B8: VE PROPOSAL: TO USE DOUBLE GRATE INLETS RATHER THAN TWO SINGLE INLETS IN CERTAIN CONDITIONS:

Whenever the hydraulic demand exceeds the capacity of one grate inlet, consideration should be given for a double grate inlet rather than two single inlets.

The use of a double grate inlet results in considerable savings in pipe connections, drainage structure, and installation. In addition, maintenance of a double grate is less than for two single grate inlets.

In a study by West Virginia Department of Highways, annual savings of $34,000 would have been realized had they used double grates in lieu of two single inlets.

Gutter flow determines inlet spacing and can be estimated from hydrologic data. When conditions warrant, normally in a sag vertical curve (sag), the use of double grate inlets may be the most economical solution.

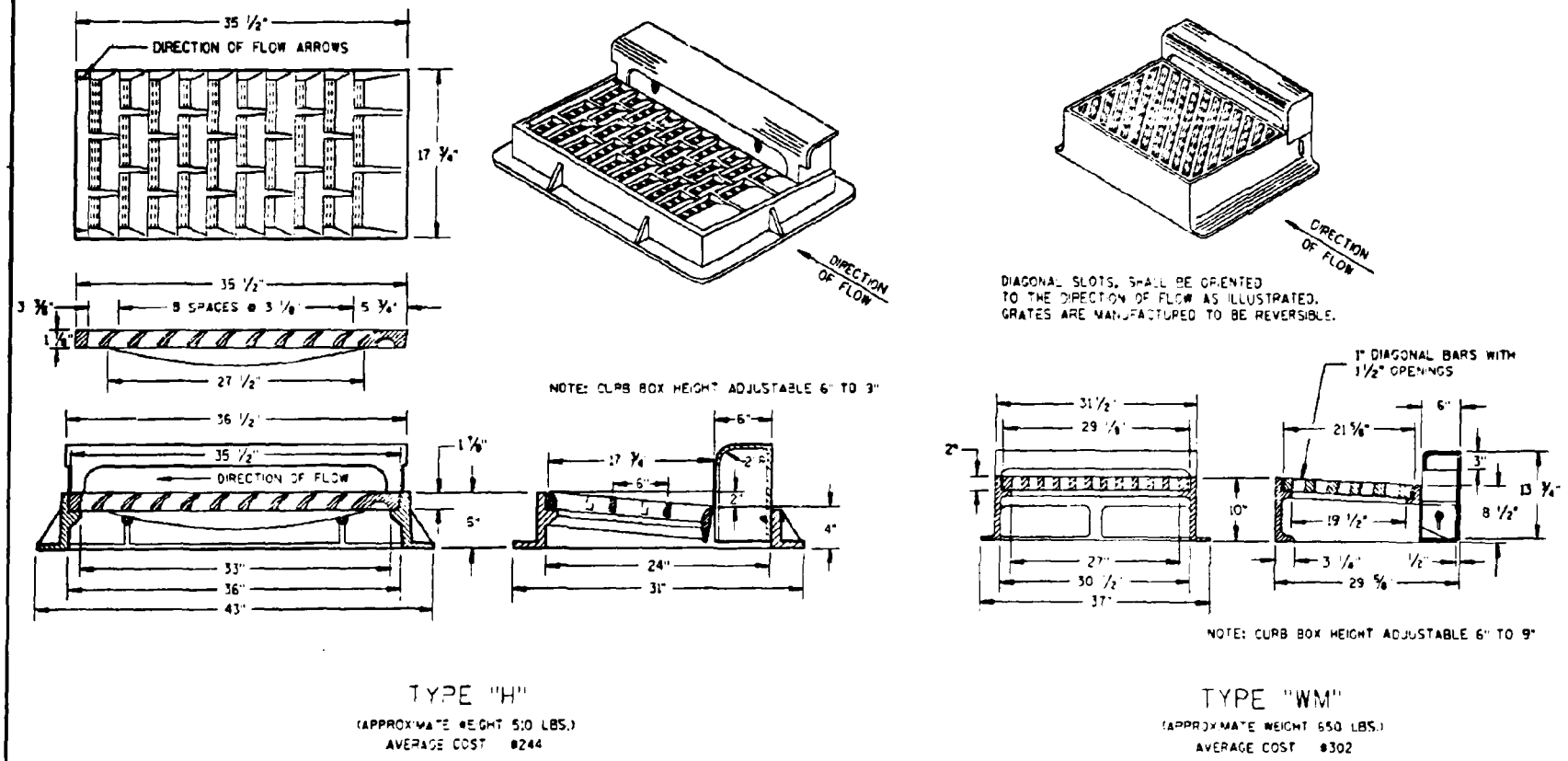
In sags, multiple grates may be oriented either parallel or normal to the curb depending upon the proximity of the traffic and other design considerations.

On grade, grates are most effective when spaced separately to allow bypass to flow to the gutter.

B9: VE PROPOSAL: TO REDUCE THE NUMBER OF STANDARD GRATES AND MANHOLES:

A large number of patterns, molds and castings now exists due to the innumerable types specified by various agencies in any given area. This large inventory requires the suppliers to invest considerable money and space for this purpose, and any unnecessary expenses will be reflected in prices across the board. (figure 12)

It is therefore incumbent upon all agencies to minimize



TYPE "H"

(APPROXIMATE WEIGHT 510 LBS.)
AVERAGE COST $244

TYPE "WM"

(APPROXIMATE WEIGHT 650 LBS.)
AVERAGE COST $302

Figure 11

COST AND WEIGHT COMPARISON OF WISCONSIN DOT INLET COVERS WITH APPROXIMATELY THE SAME GRATE SIZE

the total number of types required of industry. A careful review may show that the present diversity is excessive. A much smaller number of castings may serve the needs of the agencies in any given area without any sacrifice in the quality of drainage.

Drainage items that require large initial costs to develop, such as molds for cast iron grates, frames and curb forming "mules," should be standardized to the extent that is practical within a state or region. A state DOT can influence the county and city agencies to agree on designs and lead to standardization.

Specifications for other items like inlet and manhole structures can be looser to permit contractor and supplier innovation.

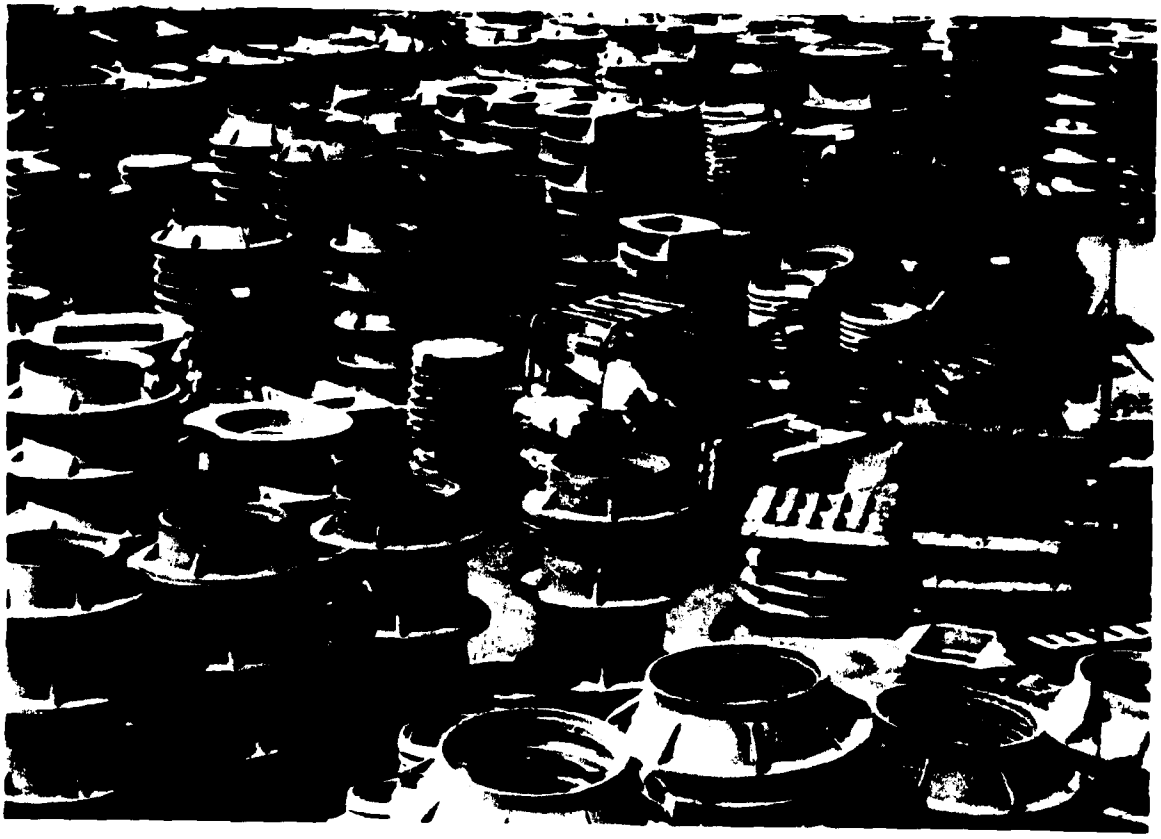


Figure 12
Profusion of Castings in Foundry Storage Yard

B10: VE PROPOSAL: TO USE AN INLET ADJUSTING DEVICE:

The adjustment of inlet grates and access covers to match the curb pan or pavement has been accomplished with a variety of materials and often with varying degrees of success. This variability has often led to deterioration of the interface structure.

The Wisconsin DOT designed and has tried an "Inlet Adjusting Device" (IAD), fabricated from cast iron, to close the area between the top of the catch basin and the grate or lid frame casting and facilitate the placement of concrete to support the frame casting. The upper portion consists of a flange and skirt that slips into the lower frame to seal the area between the catch basin and the frame casting.

The frame casting supported by the upper lid of the IAD is adjusted to position by placing three stacks of bricks between the upper and lower lids of the IAD. When the adjustment is completed, concrete is poured around the IAD and the frame casting. The IAD also provides for some movement between the frame casting and catch basin.

Figure 13 shows the deterioration that can occur to block and mortar under drainage castings. Figure 14 shows an Inlet Adjusting Device

Figure 15 shows an IAD installed.

B11: VE PROPOSAL: TO MINIMIZE CLOGGING OF INLET GRATES:

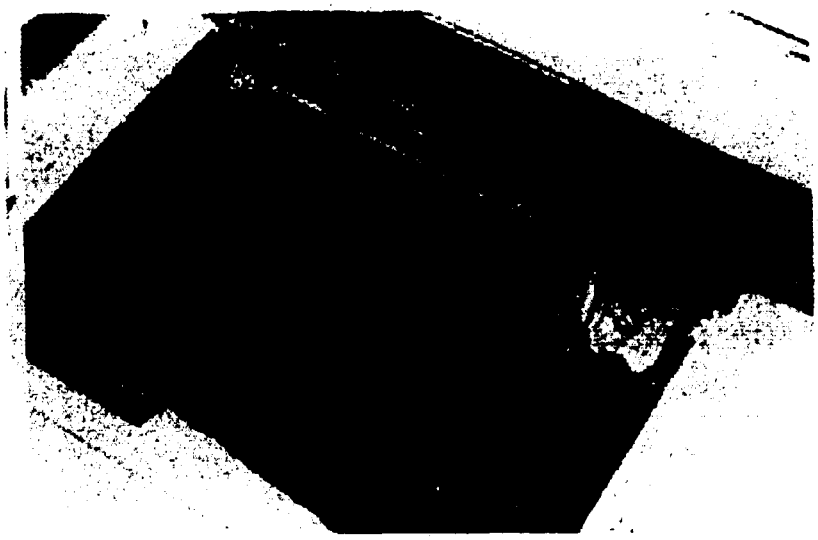
Clogging of inlet grates can drastically reduce hydraulic efficiency and can present a costly maintenance problem.

Experience has shown that where bars or vanes are closely spaced, debris, such as trash, leaves, and small stones, can block entry of water (Figure 16).

Grates with wider spacings of bars or vanes allow passage of higher percentages of such debris.

Wider spacing of bars or vanes may cause hazards for bicycles, but a compromise can be reached by the use of tilt-bar or vane grates. Test results in FHWA-RD-77-24, Bicycle Safe Grate Inlets Study, Volume 1, show that wider spacings can be accomplished without bicycle hazards using tilt-bar or vane grates and achieve greater efficiency in debris handling than those with narrow openings such as those on a parallel bar grate.

This VE Proposal is to maximize grate openings without causing hazards to bicycles or pedestrians Figure 17 gives one such inlet grate.



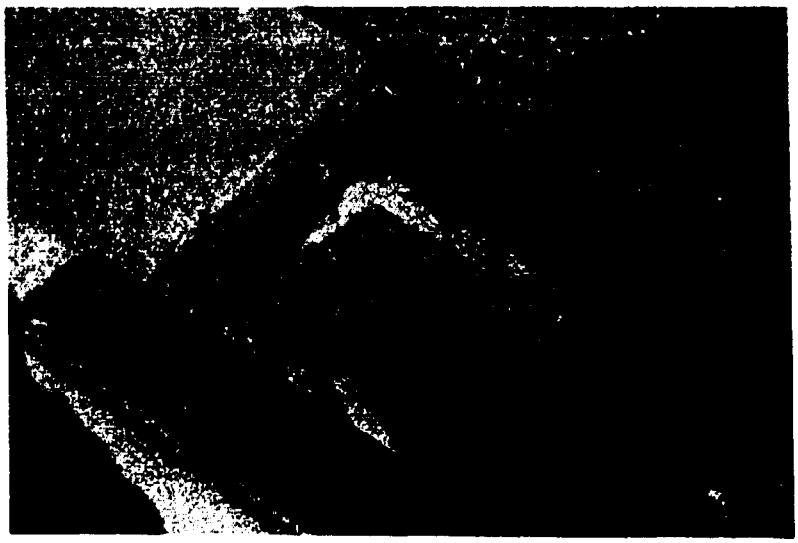


Figure 13

Deterioration of Block and Mortar under Drainage Castings

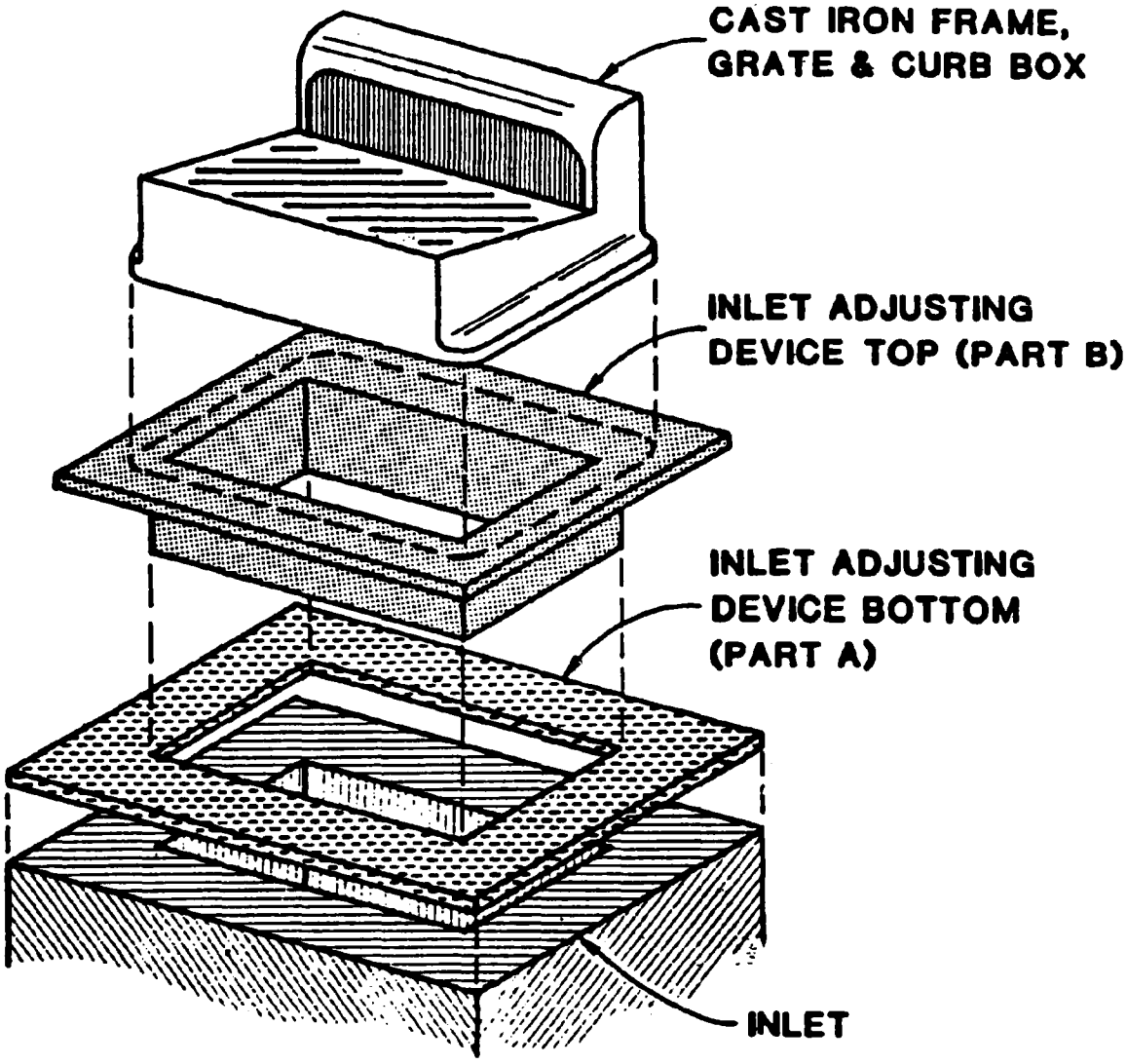


Figure 14
Inlet Adjusting Device Components
Source: Wisconsin Department of Transportation

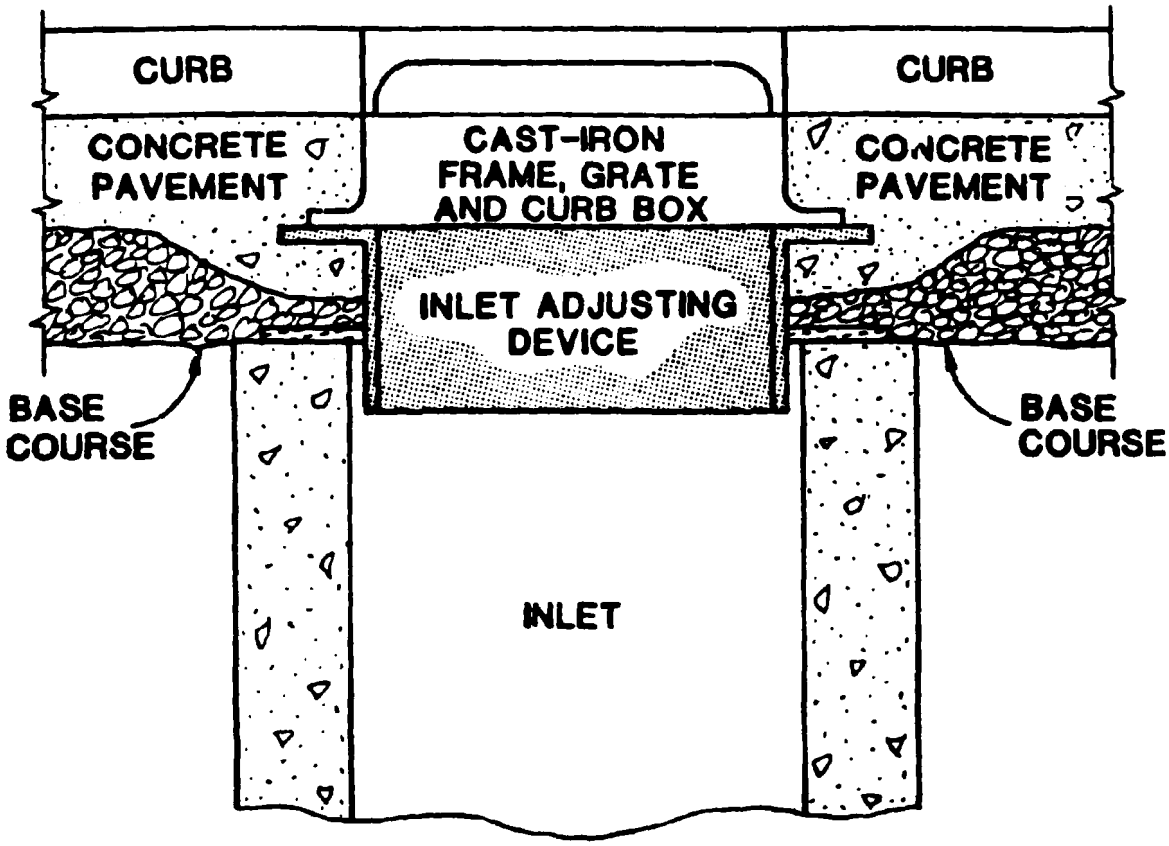


Figure 15

Installed Inlet Adjusting Device

Source: Wisconsin Department of Transportation

Figure 16: Closely spaced bars or vanes may stop too many small stones and lead to excessive clogging.

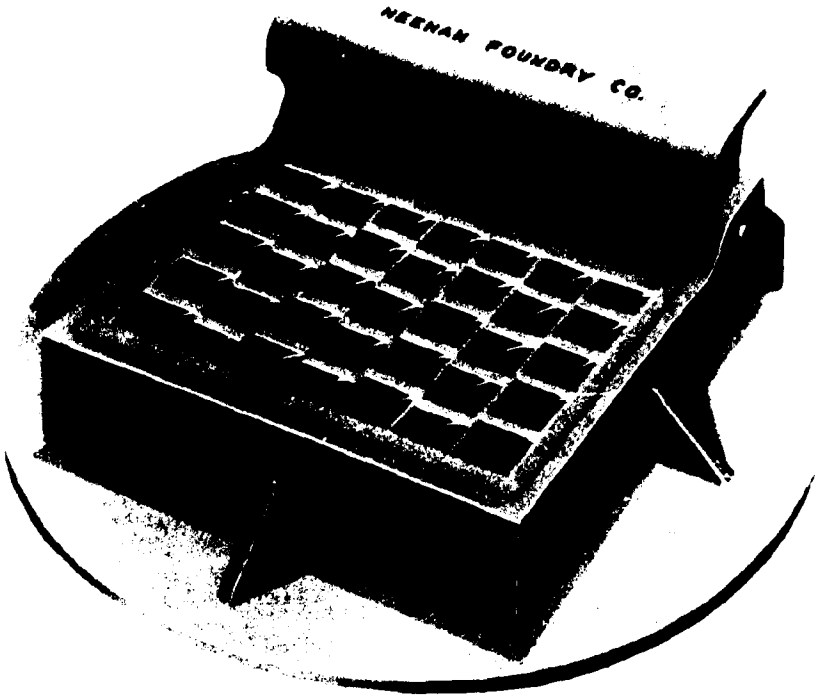


Figure 17
Typical Vane Type Inlet Grate

Throughout this report the VE Team proposed the use of broader specifications and any other methods that would encourage the use of different materials, shapes and methods that would satisfy the necessary functions and reduce the Life Cycle Costs of the highway agencies. This is a case where the use of materials other than cast or ductile iron for castings led to the use of steel to form the vanes for drainage inlets. Although this was an economical solution, it may have caused a problem in clogging more quickly than the cast iron grates, simply because steel can be rolled in much thinner shapes than iron can be cast, and these thinner sheets can be placed much closer together. Since they are thinner and weaker than cast iron, they could not be spread further apart because they would deform too easily. This illustrates one of the disadvantages of broader specifications. It does require the agencies to more carefully review new products and substitutions.

B12: VE PROPOSAL: TO ELIMINATE METAL FRAMES FROM CONCRETE INLET BOXES IN MEDIAN DITCHES:

Flush inlet boxes are normally used in median ditches. Some agencies cast the concrete for the box directly around the grate, while others mortar a frame to the top of the box.

No difference in performance was distinguished between the inlet boxes with steel frames and those without, therefore it is recommended that the metal frames be eliminated and thereby reduce cost.

This is not recommended for inlets subjected to traffic.

C. CURBS AND GUTTERS:

C1: VE PROPOSAL: TO STANDARDIZE THE DESIGN OF CURBS AND GUTTERS.

The shapes and sizes of curbs have proliferated over the years as each highway agency and local government adopted their own standards for street construction. The curb shape selected as standard may have been arbitrary and adopted for the sake of uniformity. A six inch curb height, for example, is common.

Variations in curb shape came about because of differences in curb width, batter angle of front face, and radii at the curb top and flow line. Small variations in curb shape seem to have little engineering justification. Standardization would reduce the number of forms and "mules" and benefit everyone in the long term.

ADVANTAGES OF STANDARDIZATION:

o A more limited number of carefully selected shapes Would offer the potential for the following advantages:

o Reducing average cost to contracting agencies.

o Contractor's investment in curb forms and slip form mules is better used as repeated use of the shapes is assured.

o Design efficiency will result as designers become familiar with the standard shape and specify it frequently.

o The proliferation of odd shapes and sizes would be eliminated.

o Centralized design of the shapes provides a focal point for input of experience.

o Standard designs should represent the best shapes from an engineering standpoint

o Associated industries like manufacturers of slip form pavers and foundries that make the cast-iron drains would benefit from fewer curb shapes.

o Reduces number of castings stocked for maintenance purposes.

IMPLEMENTATION OF STANDARDIZATION:

Despite the obvious benefits, standardization of curbs and gutters has not taken place. Most other proposals within this report can be adopted, modified or rejected by the individual State Agencies, but Standardization requires the close cooperation among many State Agencies.

The benefits are so significant that serious effort is recommended to make it work. A few suggestions are:

o Any agency can decide to show preferred shape on standard drawings, as well as alternative shapes, requiring contractors to bid both ways.

o Any agency can provide training courses that include encouragement of the use of the standard shapes and sizes.

o Any Agency can include the standards in their design manuals.

o Nationally recognized references like AASHTO publications and NCHRP reports, can encourage the use of the standard shapes and sizes of curbs and gutters.

o Any State Agency can submit articles to regional and national publications encouraging the adoption of standards and presenting opinions of highway officials, suppliers, contractors, and others with who they have had experience.

o Two or more States can agree to adopt the same standards and begin a regional standardization program, with the hope that it would broaden to include other adjacent States.

o Regional standards could be publicized and eventually result in a National consensus and standard.

o A National standard will yield the greatest benefit. Every effort should be made to avoid the establishment of regional standards that aggressively and arbitrarily defend their design and prevent the formation of a National standard.

o The publication of this portion of the VE report in several publications that reach the various agencies, may result in sufficient interest to initiate the goal of a National standard.

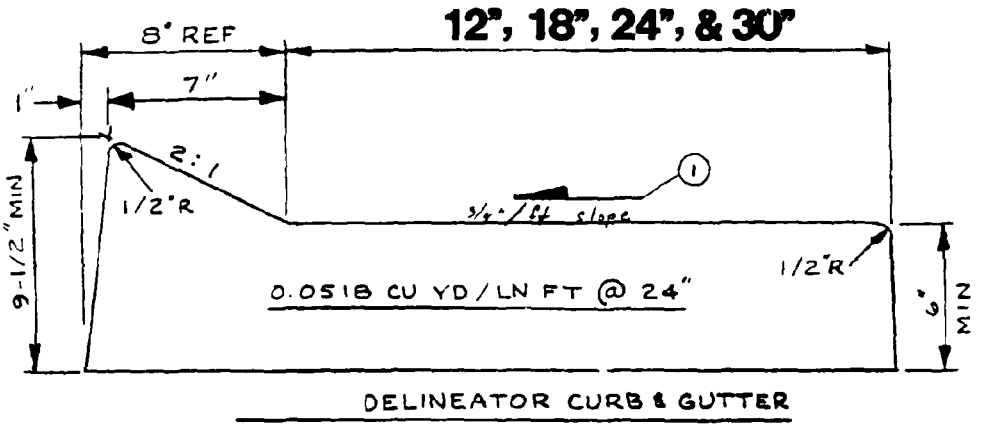
o Suggestions for implementation will be welcomed.

C2: VE PROPOSAL: TO HAVE ONLY SIX STANDARD CURBS AND GUTTERS.

Standardization must start somewhere. The VE Team considered many alternatives and offer these two basic types and three widths to serve as the new standard. These will satisfy the requirements of most situations and will agree with the recommendations of AASHTO types C and H, and report 150 of NCHRP.

Figure 18 illustrates the standards recommended by this study, This is a typical cross section of the forming device (commonly called a "mule"). The contractor can rotate the slip forming machine to obtain the proper cross slope.

C3: VE PROPOSAL: TO MINIMIZE THICKNESS OF GUTTER PANS.



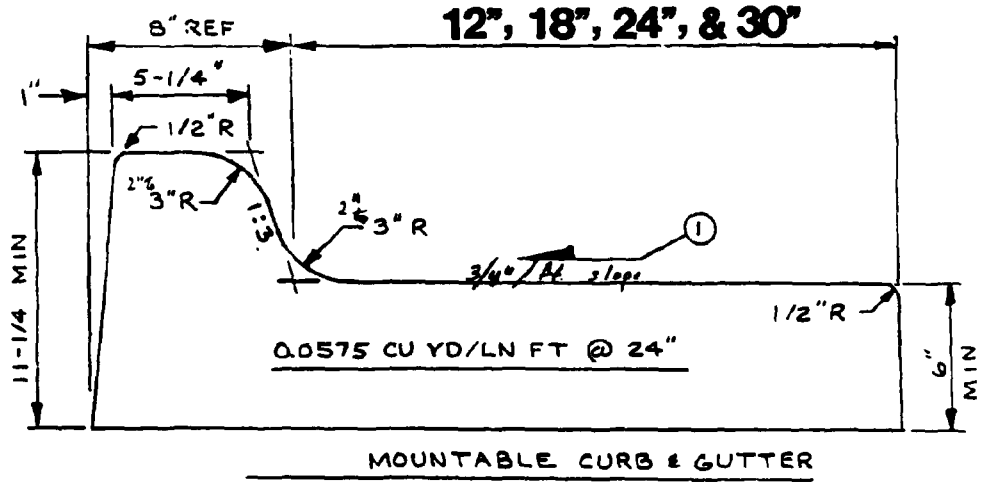


Figure 18
VE Team Recommendation for Standardized Curb and Gutter Types

The variation of thickness of gutter pans among the various highway agencies, appears more to be a matter of preference and tradition as opposed to sound engineering and experience. This VE Proposal hopes to highlight this feature and be a nucleus upon which to build a standard.

Many Agencies have had good results using a gutter thickness of 6" (23.6 cm). It is therefor proposed that a standard be established of 6" (23.6 cm) minimum thickness for gutter pans.

For commercial drives and where unusual conditions exist, designers will use good engineering practice to determine the proper thickness. For most situations, calling for a minimum of 6" will save many States now using thicker gutter pans considerable money.

This proposal will not preclude contractors from increasing the thickness for construction economies or convenience.

C4: VE PROPOSAL: TO ELIMINATE REINFORCEMENT IN CURBS AND GUTTERS.

Among the States contacted, some used steel reinforcement in their curbs and gutters. Most did not. Obviously reinforcement increases the initial cost.

Equally obvious, if the elimination of reinforcement increased maintenance problems and thereby increased Life Cycle Cost, the issue would require deep analysis.

Those States reporting in this study, did not show any increase in maintenance costs or extent of cracking by the elimination of reinforcement.

This VE Proposal recommends the elimination of reinforcement in all curbs and gutters, except where it is an integral part of a concrete roadway, at catch basins or curb boxes. A minimum curb thickness of 8" (20 cm) at the curb/gutter interface, will provide adequate strength.

The key to this proposal is the effect on Life Cycle Cost. As stated, no problems were reported by the States that now use no reinforcement. However, no definitive, carefully monitored studies have been made to prove the LCC is deleteriously affected.

The experience of other States, using reinforcement in curbs and gutters or not, will be welcomed so that future reports can define the value of the proposal.

To those States now using reinforcement in their

curbs and gutters, the elimination of the steel will reduce initial costs substantially. One State reported savings of $0.52 per linear foot by the elimination of the reinforcement in curbs and gutters. With an annual usage of 200,000 linear feet of curbs and gutters, for example, the saving would be $100,000. per year.

Other aspects of the design affect the integrity of curbs and gutters. For example, Minnesota DOT uses contraction joints at ten foot (305 cm) intervals in curb and gutter adjacent to bituminous, but expansion joints are not placed at regular intervals. Adjacent to concrete pavement, expansion joints are spaced at the same interval as the pavement joints.

C5: VE PROPOSAL: TO SPECIFY BATTER FOR ALL BARRIER CURBS

Batter has long been recognized as a safety feature for motorists, and for that reason alone it is justified.

Batter simplifies the placement of curbs and gutters by slip forming equipment or by manual methods.

Batter lessens the chance of snow plow damage.

This agrees with AASHTO Type A Curb.

C6: VE PROPOSAL: TO MINIMIZE TIGHT SPECIFICATIONS.

Alternate construction methods should be permitted to the extent that they produce an acceptable result. This proposal recommends that specifications be carefully reviewed as they arise in design to determine if the dimensional tolerances are realistic and excessively tight.

Write specifications as broadly as possible when describing radii and similar dimensions. Good engineering practice will dictate when a dimension should be tight, knowing that contractors and suppliers often must increase the price when tied down excessively.

Not only dimensions, but methods should be as broadly stated as possible. For example, the contractor should normally be given the alternative of slip forming. Encouraging the suppliers and contractors to be innovative can often be as simple as broadening the specifications.

C7: VE PROPOSAL: TO INCREASE THE HYDRAULIC CAPACITY OF GUTTERS.

Use a minimum gutter cross slope of 3/4 " (19 mm) per foot to increase the capacity of the gutter to serve as an accumulator of runoff, and to increase the depth of water

over the grate.

Increasing the cross slope enhances its ability to channel water to the inlet and thereby increase their efficiency. With greater efficiency, the designer may be able to reduce the number of inlets and affect savings in the drainage system.

Where possible, use the same technique of sloping the parking lanes and shoulders to also serve as collectors and aid the runoff to the drainage inlets. A minimum of 3/4" per foot (0.063 m/m) is recommended.

Studies by West Virginia show that the cost of drainage inlets per linear foot (30 cm) of roadway was reduced by as much as $16. changing from a 1/4" (6.35 mm) per foot (30 cm) cross slope of gutters to a 3/4" (19 mm) per foot (30 cm) slope.

C8: VE PROPOSAL: TO USE CURBS TO MINIMIZE RIGHT OF WAY:

Curb and gutter can be effectively used to minimize the right of way requirements including property damage that would otherwise result from the construction of a drainage ditch. Short segments of curb and gutter can be designed to drain into a ditch located beyond the affected property. Otherwise storm sewer may be required. However, curbs should generally not be used on high speed highways where roadside safety is a significant consideration.

Figure 19 illustrates the difference in right of way requirements for a cross section that uses curb and gutter and one which uses a ditch.

C9: VE PROPOSAL: TO AVOID OVERSIZED DRAINAGE INLETS:

An oversized casting of a drainage inlet that extends beyond the gutter pan into a flexible bituminous pavement interferes with the placement and compaction of the pavement. It may, therefore, result in settlement or rutting because of poor compaction of the flexible pavement.

Castings protruding into a rigid concrete pavement may present comparable construction problems and result in cracking and spalling adjacent to the frame as a result of differential thermal movements and stress concentrations. This will eventually result in unacceptable pavement conditions and increased maintenance costs.

This proposal recommends the careful sizing of gutter and drainage castings so that the casting fits entirely within the gutter.

Figure 19
Use of curb and gutter to minimize Right-of-Way

In the foreground the Right-of-Way is clearly defined by the curb and gutter. In the background the ground slopes gradually away from the road.

Curb and gutter has been used to define and reduce the required Right-of-Way. However, its use in high-speed rural and subruban locations is inappropriate. An errant vehicle striking a barrier curb will often not be redirected. Rather, it may vault over the curb, with loss of braking and steering control until returning to grade at some distance behind the curb. Even on low-speed facilities care needs to be exercised that the introduction of a curbed street section does not create a problem for an approaching driver who is expecting a traversable roadside.

Figure 20
Cast Iron Grate Assembly Encroaching into Pavement

Figure 20 shows a casting that was recently placed and already the pavement is showing signs of distress due to the intrusion of the casting into the traffic area.

Whether the pavement is rigid or flexible, it is preferable to hold the casting without encroaching on the pavement.

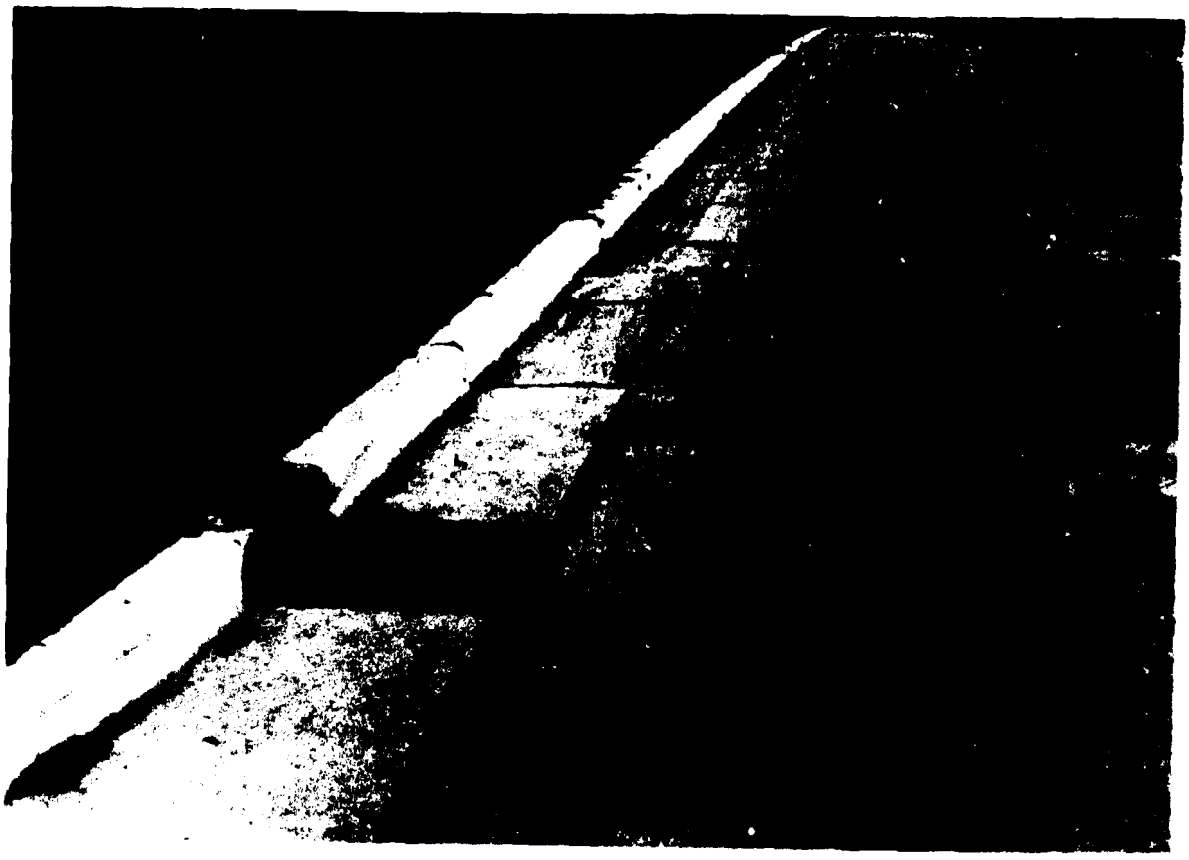


Figure 21
Cast Iron Grate Assembly Constructed Within Curb and Gutter

Figure 21 shows a gutter that has been made wide enough to accommodate the grate casting. This minimizes the stresses caused by thermal expansion/contraction, vibration, heavy impact, snow plows, differential loading, etc.

The Standard Curb and Gutter recommended in VE Proposal C2, page 38, originally was 24" (60.96 cm), but in review, the Wyoming DOT representative on the AASHTO Committee on Hydraulics and Hydrology reminded the team that the maximum 24" (60.96 cm) width they first considered, would eliminate many efficient castings, and suggested the maximum be increased to 30" (76.2 cm). The team accepted this modification.

Figure 22
Cast Iron Casting with Broken Concrete Pavement

Figure 22 shows a casting in a rigid concrete pavement section that has caused considerable distress in the pavement. Repair is costly.

The cracking and spalling was caused by the intrusion of the casting into the pavement. Shock, thermal forces, vibration and other stresses concentrate at the edge of the casting and failure of the pavement results.

APPENDIX A

The Department of Transportation of four States supplied the team members for this Valve Engineering Study.

They were:

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Madison, Wisconsin 53707

Each State prepared a report on portions of this study that they selected to pursue. This report is a compilation of the major findings recorded therein.

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*These are the four members of the final VE Team that developed the draft that was the base document for the preparation of this report.

* U.S. Government Printing Office : 1990 - 717-000/27165

A NOTE ON THIS PUBLICATION

This report is the seventeenth of a special series on highway maintenance that is being developed by cooperating groups of State highway agencies and is being issued under the sponsorship of the Office of Implementation, Federal Highway Administration.

Other reports in this series are:

Snow and Ice Control - Materials	FHWA-RD-75-524
Snow and Ice Control - Operations	FHWA-TS-77-208
Shoulder Maintenance	FHWA-TS-77-210
Repair of Continuously Reinforced Concrete Pavements	FHWA-TS-78-215
Bituminous Patching	FHWA-RD-78-220
Sign Maintenance	FHWA-TS-78-223
Bridge Painting	FHWA-TS-79-202
Traffic Striping	FHWA-TS-79-219
Rest Area Maintenance	FHWA-TS-80-210
Repair of Concrete Pavement Joints	FHWA-TS-80-215
Mowing Operations	FHWA-TS-82-209
Drainage Maintenance	FHWA-TS-82-223
Crack and Joint Sealing	FHWA-TS-84-221
Guidelines for Slope Maintenance and Slide Restoration	FHWA-TS-85-231
Guardrail and Impact Attenuator Repair	FHWA-TS-87-226
Repair of Transverse Cracking in Asphalt Concrete	FHWA-TS-89-010