Missouri
Department
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December 14, 2007

MoDOT Design Division
Attn.: Jay Bestgen
1320 Creek Trail Dr.
Jefferson City, MO 65109

Dear Mr. Bestgen:

On behalf of the Practical Design of Traffic Signals Team, I am submitting an application for the Practical Design, 2008 Awards for Excellence, Non-Project Practice category.

Comprised of MoDOT employees from several divisions and three districts, this team formed to reduce the cost of traffic signal installations. This was a team approach to looking at the design and construction of a traffic signal overall, rather than project specific. Every component of the signal installation was scrutinized. These changes affect every signal installation thereby promoting consistency in design and construction without compromising safety, operation and maintenance. The savings are repeatable and can be incurred over and over, not just once. These changes are also transferable to cities, counties and developers and will provide them with savings as well, so the effects can be more far reaching than MoDOT alone. Manufacturers, suppliers and contractors were consulted for cost-saving ideas. Construction issues were researched and also the design of signals. Changes also incorporate design choices, and provide better tools to make decisions.

Within seven months, the team made a presentation to management. The recommendations showed MoDOT could save $1.5 million each year and reduce the installation cost of a signal by 18.5 percent. These savings reflected material cost only and additional savings could be realized if contractors pass on any savings from lowered installation costs through easier construction methods. Another source of savings, which was identified, could also be realized by further structural review of the signal poles.

After the presentation, many districts were excited to try the recommendations. We were able to provide the information and some projects incorporated the recommendations. Changes to standard plans, specifications and the Engineering Policy Guide were approved in November 2007 and will be effective February 2008.

This team acted quickly and took risk but provided a result that all are proud of. The results are impressive and show when we really take the time and look, we can find ways to save money. This effort was truly what practical design is all about, finding ways to cut cost that are repeatable without impacting safety, operation and other divisions.

Sincerely,

Julie Stotlemeyer
Team Leader

Practical Design

2008 Awards for Excellence

MoDOT

ACEC Missouri

American Council of Engineering Companies of Missouri

Summary

Challenge

At the inception of practical design, designers began to look for ways to reduce the installation cost of traffic signals. Although many of the ideas reduced cost, many of them decreased safety and operation and increased maintenance. In the spirit of practical design, the Traffic Division led an effort to look for ways to reduce costs without compromising safety, operation or increasing maintenance. The goal was to find a ten percent savings. A quick action team was formed and the research began.

Team history

In January 2007, the team was formed consisting of representatives from Traffic, Design, Construction and Materials, the Engineering Policy Group and three districts. Participation from Bridge Division, manufacturers, and contractors was also obtained.

The team studied all signal bid items from 2004-2006, other state DOT standards as well as all Value Engineering ideas submitted by contractors. Pole companies and major signal installers were consulted for cost-saving ideas. The team also acquired the services of a pre-approved engineering consultant to analyze MoDOT’s traffic signal wiring sizes and ensure compliance with the National Electrical Code.

Using the pay items, the team assessed traffic signal components that made up 85 percent of all traffic signal installation costs during the years 2004 through 2006. In order to lower costs but not affect safety, operation or maintenance costs, the team scrutinized the signal head support alternatives, mast arm length increments, upright pole dimensions and the concrete base’s dimensions and reinforcing steel design. For the electrical equipment, the team studied the consultant’s wiring proposals for wire diameters and color codes, conduit diameters, the controller base’s dimensions and material, pull box sizes, spacing and apron options and the traffic signal’s detection systems.

The team presented the practical design recommendations in July 2007. Changes to standard plans, specifications and the Engineering Policy Guide were approved in November 2007 and will be effective February 2008.

Savings

During the years 2004 through 2006, MoDOT spent almost $24.4 million on permanent traffic signal installations, $160,418 per signal. The Practical Design Team identified a savings of 18.5 percent. Had the recommendations been in effect during 2004-2006, MoDOT would have saved approximately $1,503,000 per year. Bringing the average installation cost to about $130,740.

This reduction is measured in material costs only. Additional savings could be realized by our contractors and passed on to us from lowered installation costs through easier construction methods. The team also anticipates additional savings by lowering pole costs after further structural review.

Backup Information

Below are excerpts from the Practical Design Team of Signals final report to management. This outlines in detail, the signal components researched, the recommendations and the savings identified.

Traffic Signal Detectors

Current Practice
Current design guidelines provide some of the advantages of one detector system over another, but the discussion is limited. The type of detector system selected for a location is left to the discretion of the district. As a result, too often districts are specifying video detector systems where they are not really needed; at double the installation cost where induction loop detector systems would have been practical. In addition, the current selection process does not take into consideration life cycle costs and should. For example, the current lifespan of a video detector system is approximately half that of an induction loop system.

Proposed Practice
In most applications, there is no overall advantage in using one detector system over another. Therefore, instead of the district selecting what system is to be used at a given location, it is recommended that we allow industry to be the driving force by alternate bidding this item of work. With alternate bids, it is also recommended that life cycle costs for determining the low bid be included in proposals where traffic signals are a major item of work.

Because there may be cases when one system is desirable over other systems, specifying certain detector systems for a given location is recommended when the district can show through a design exception that it is practical to do so. To aid the districts in selecting the appropriate system in such cases, it is recommended that more guidance be included in the Engineering Policy Guide (EPG).

Savings
It is anticipated that alternate bids can be used to determine which detector system is used 90 percent of the time. Installation costs for induction loop detectors are estimated to be:

Type of Intersection	Cost Per Intersection
One Lane Main Street, One Lane Side Street	$8,260
Two Lane Main Street, One Lane Side Street	$9,620
Three Lane Main Street, One Lane Side Street	$10,980
Three Lane Main Street, Two Lane Side Street *	$12,340
Three Lane Main Street, One Lane Side Street	$13,700

* Considered most common intersection.

In 2004–2006, 215 video detector systems were installed at an average cost of $22,694. If 90 percent of these systems were allowed to be bid as alternates, the estimated savings would had been $2,003,499 for three years, $667,833 per year. This represents an 8.22% overall signal cost reduction or $14,056 per signal.

Traffic Signal Post Bases

Current practice

<u>BASE EMBEDMENT:</u>
Currently designers reference Standard Plan 902.30 to determine the size of the signal post base and the quantities of concrete and steel. Adjustments are made to the signal post base embedment based on pavement superelevation and/or base location in the foreslope. MoDOT current design of signal post bases is based on 1994 AASHTO Standard Specifications. The most current design criteria, AASHTO 2001, would result in a substantial increase of material that would be required due to added fatigue design criteria. MoDOT has chosen not to use AASHTO 2001 because we have not experienced any performance issues with these structures and it would be very costly due to increase material thicknesses according to the new fatigue provisions.

Use of a minimum design wind speed of 90 mph and a percent allowable stress of 133% is also part of our current practice when evaluating the wind load versus the dead load on our signal structures. Prior to 1996 the minimum design wind speed of 80 mph and a percent allowable stress of 140% were used until some problems were identified with fatigue of the weld of the mast arm/signal post connection. The problem was associated with one manufacturer's post and mast arms.

Presently designers determine the appropriate foundation based on the signal post type (B = Butterfly, C = Cantilever) and the mast arm length. When the foundation has been determined, then the steel and concrete quantities can be determined from the corresponding table on Standard Plan 902.30. Any adjustments for pavement superelevation or foreslope placement to maintain the standard vertical clearance over the driving lanes are also made at this time.

BASE REINFORCEMENT:
As a rule of thumb, current practice utilizes 1% steel cross-sectional area for ductile structure minimum reinforcement. Standard Plan 902.30 specifies 13 - #8 reinforcement bars equally spaced, with #4 tie bars spaced at 12".

Proposed practice

BASE EMBEDMENT:
It is recommended to continue using AASHTO 1994 specifications, with 80 mph wind speed and 140% allowable overstress. The designer will determine the mast arm type, then use the proposed embedment lengths, corresponding concrete and steel quantities contained in the following tables:

Required Embedment Length (3.0' Dia.) "A"		
Mast Arm Type (C – Cantilever, B – Butterfly)	C	B
Light/Short (15' – 25')	*9.0'*	*10.0'*
Medium (30' – 35')	*9.5'*	*11.0'*
Heavy/Long (40' – 55')	*10.5'*	*12.0'*

Quantities C Posts (3.0' Dia.)			
A (ft)	Base	Concrete (Cu. Yds)	Steel (lbs)
9.0	Type A	2.88	282
	Type F	2.36	231
9.5	Type A	3.01	292
	Type F	2.49	240
10.5	Type A	3.27	318
	Type F	2.75	266

Quantities B Posts (3.0' Dia.)			
A (ft)	Base	Concrete (Cu. Yds)	Steel (lbs)
10.0	Type A	3.14	308
	Type F	2.62	257
11.0	Type A	3.40	334
	Type F	2.88	282
12.0	Type A	3.67	360
	Type F	3.14	308

BASE REINFORCEMENT:
It is recommended to use 13 - #6 reinforcement bars equally spaced, with #4 tie bars spaced at 12". A reduction of approximately 35-40% in steel weight is realized. The reduction in the overall weight will simplify construction methods and labor necessary to build and place the reinforcement steel.

Savings

BASE EMBEDMENT and REINFORCEMENT:
The proposed changes in the base embedment and reinforcement will result in both materials and construction methods savings estimated to be 0.43% annually of the total signal installation costs or approximately $34,667, $104,000 over three years.

Mast Arms

Current practice
Structurally, mast arms are designed based on worst case loading criteria and allowable stress and wind speeds of 133% and 90 mph, an increase over the AASHTO 1994 specifications. Depending on the lighting scheme needed, signal poles may or may not have luminaires. To accommodate this need, two heights of poles are provided. Mast arms, the horizontal member, come in lengths from eight to 54 feet, in one-foot increments. Bolt circles for the base plate of the upright vary by manufacturer. The designer indicates signal head spacings on plan sheets. Manufacturers weld pipe nipples for signal head attachment at those locations shown on the plans.

Prior to 1996, standard AASHTO loading was used. MoDOT experienced some mast arm failures in 1996, predominately by one company, and allowable stress and wind loads were increased. From pay item history, pole prices increased 4.3 percent more than inflation for that time.

Proposed practice
Structurally design mast arms based on three loading criteria; light, medium and heavy and use standard 1994 AASHTO loadings, 140% at 80 mph. Use one height of pole and if signal pole lighting is needed, a luminaire attachment arm will be used (see Appendix 3). Group mast arms lengths in five-foot increments, 15 to 55 feet. Standardize bolt circles and utilize brackets to mount signal heads.

Savings
Pole prices increased 4.3 percent more than inflation for 1997 - 1999. Therefore by returning to standard AASHTO loads, we estimate saving approximately three percent on pole costs each year, nine percent over three years. For a three-year period, poles cost $3.469 million, saving $312,210 over three years or $104,000 each year, 1.2 percent overall savings.

Eight- to ten-foot arms were not used in a three-year period and eleven- to 15-foot arms consisted of only 5.5 percent of the total quantity ordered, yet some of these were the most expensive cost per foot lengths. By eliminating those shorter arms and consolidating the lengths into five-foot increments, larger quantities will result and costs will be reduced. Manufacturers estimate a 10 percent savings, $346,000 over three years, $115,633 each year, 1.4 percent overall savings.

Using brackets to mount signal heads will eliminate manufacturers' time to install pipe nipples and the need to have plan sheets. Poles can be made ahead of time rather than waiting for job specific plans. This represents a $280 savings per head. MoDOT installed 2275 heads in three years. This would result in a savings of $637,000 or 2.61 percent of overall costs.

By implementing all the mast arm changes, the estimated savings is 5.21 percent in overall signal costs, or $8909 per signal installation.

Cable

Current practice
Currently, MoDOT uses 2-, 3-, 5-, and 7-conductor, #12 AWG wire for signal installations. This wire has PVC insulation and utilizes a standardized color-coding for traffic signals.

Power cable currently used is a minimum #8 AWG and has a thick insulation for wet and direct bury applications; namely THW, USE, RHW. However, this wire is difficult to find, costly and is placed in conduit.

Proposed practice
With the conversion to LED's for signal indications, the power consumption has been reduced by 75%. Intersections are consuming only about four amps of power. This reduction in power consumption allows us to evaluate the size of wire. A #16 AWG wire could easily be used. However the challenge came with trying to find market-available signal wire in that size. Further investigation showed a 2-conductor and 7-conductor, #16 is available with polyethylene insulation but 3- and 5-conductor is not. Wiring practices were looked at and the decision to use 7-conductor, #16 with polyethylene insulation and standardized color-coding for traffic signals.

Again, the use of LED's allows us to reduce the minimum power size of cable to a #12 AWG. Since we utilize conduit for the placement of the cable, we can allow more readily available and cheaper type wire; namely THHN/THWN.

Savings

For a three-year period, 7-conductor, #12 AWG cable cost $273,884. Manufacturer cost for 7-conductor #16 AWG is $227,003, saving $46,881. Combining 3-conductor, 5-conductor with 7-conductor will save $9,133. Reducing power cable from #8 to #12 AWG saves $27,790.

Implementing all of these changes, the estimated savings is 0.34 percent of overall signal costs, or approximately $558 per signal.

Conduit

Current practice

Currently, MoDOT uses 4" conduit as the standard conduit size for containing controller cables for a traffic signal. The 4" conduit is the standard because the current size, 12 gauge conductors, and number of the controller cables for a typical signal installation requires so much area that only a 4" conduit will suffice.

In addition, between the signal controller and the controller pull box are two runs of 4" conduit. This is done to accommodate the typically large amount of controller cables running from the last pull box to the controller.

Typically, 3" conduit is used only for fiber optic interconnection cable runs between two or more signals. Conduit used for loop detectors is 1".

Proposed practice

Due to the use of LED signal heads over incandescent light bulb signal heads the controller cable used for signals does not need to be so large. A 16-gauge controller cable is more than adequate to handle the current loading of the new LED heads. In addition, new technologies in wire insulation material have led to thinner and more resilient wire insulation jackets. These factors cause the new controller cable to take less cross-sectional area than the current controller cable.

For most traffic signals a 3" conduit will be sufficient to handle the controller wiring for a traffic signal. The dual conduit run between the controller and the last pull box can also go to 3" conduit.

This smaller conduit, while not only being cheaper material wise, should be easier to handle and install. And by going to all 3" (including interconnection conduit) MoDOT will have more uniformity in construction materials. All of which should lead to a reduction in construction costs.

Savings

The estimated savings from switching to 3" from 4" conduit amount to a 1.67% reduction in overall signal costs. This represents an estimated cost reduction of $407,858.46 from 2004 – 2006 or $2855 per signal installation.

Pull Boxes

Current Practice

<u>Intersection</u>

- Pull box design includes a concrete pad surrounding the perimeter.
- A Class 1 pull box uses 0.25 cubic yards (CY), while a Class 2 uses 0.3 CY.

<u>Interconnection</u>

- Pull box spacing is currently set at 200' maximum distance, regardless of type of cable used.
- With fiber optic as the preferred cable choice, large round Class 5 pull boxes are used to house the coiled excess needed for slack and to keep the cable above the minimum bending radius.
- This results in the largest size of pull boxes used every 200' along an interconnect run.

Cabinet Bases

Current Practice

Cabinet bases use approximately 2 CY of concrete per cabinet.

Proposed practice

Intersection Pull Boxes
Eliminate the pad surrounding the intersection pull boxes.

Interconnection
Recommended pull box spacing would be 1500’ for fiber optic cable, with Class 2 pull boxes used between intersections, as Class 2 pull boxes are large enough to house the cable at a minimum bending radius. One Class 5 pull boxes would be used at the intersection.

Cabinet Bases
Preformed cabinet bases would be recommended as a replacement of concrete bases.

Savings

The elimination of concrete pads would save approximately $92,000 per year, or 1.1% of the total cost of a signal installation.

Reduction in number and size would save approximately $85,000 per year, or 1.0% of total signal installation cost.

Utilizing preformed bases would save approximately $27,000 per year, or 0.34% of the total signal installation costs.

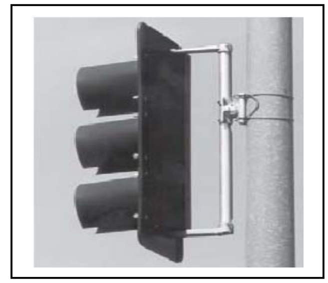
In total, there would be approximately $205,000 in yearly savings. This represents 2.5% of the total cost of signal installation, or $4275 per signal.

Before / After Pictures

Not all of the changes to the signal design and construction can be shown. Below are some of the recommended changes to signal installations.

Before | **After**

Mast Arms
Before – signal heads are attached using pipe nipples manufactured by the pole company. This requires the pole company to have specific measurements for the placement of the signal heads. Pipe nipples do not allow for adjustment in the field.
After – signal heads attached with cable brackets. Reduces manufacturing costs and allows for field adjustment.



Pull Boxes
Before – concrete pad placed around the pull box to reduce damage. Requires over 10 man-hours to form the pad.
After – by using pull boxes tested for lateral loads, damage is reduced. Cost of pull box is the same but eliminated the labor and material for the concrete pad.

Cabinet Bases
Before – concrete pad used to elevate the controller cabinet. Material and labor
After – allow the contractor to use a preformed pad. Preformed pads are easier to install, don't require concrete and can be installed quicker. Allows the contractor to begin the installation of the controller cabinet within the same day. Will result in quicker turn on of the signal which promotes uninterrupted traffic flow.

NON-PROJECT PRACTICE
2008 APPLICATION FORM
(required for each entry)

Process or Product Practical Design of Signal Installations

Description: During the years 2004 – 2006, MoDOT spent almost $24.4 million on the installation of traffic signals. A team studied all signal bid items, other state/county/city standards as well as all value-engineering ideas submitted by contractors. Industry representatives were also consulted for cost-saving ideas. An engineering consultant analyzed wire sizes and compliance with National Electrical Code. The team identified seven signal components that represented 85 percent of the signal cost. As a result, the identified cost-saving measures resulted in $1.5 million savings per year and lowered the signal material cost 18.5 percent.

Team Leader Julie Stotlemeyer, Practical Design of Signals Team

Other Key personnel (limit of 9)

Brandon Campbell	Hank Krull	Greg Owens
Jim Smith	Keith Smith	Chris Weikel
Dale Parsons (former employee)	Shirley Eslinger (former employee)	

Overall Savings: $1.5 million per year, 18.5 percent

Cost of using process or product before value analysis $160,418 per signal

Explanation Over the years, items were added to the traffic signal without fully considering the impact on the cost or constructability. Technology had also changed, but specifications weren't implemented to take advantage of the changes or keep up with the industry. This proliferation contributed to the raising cost of a traffic signal installation.

Cost of using process or product after value analysis $130,740 per signal

Explanation The implementation of LED technology in signal heads helped reduce the amount of electricity used by the signal. Using an electrical engineer, wire sizes were analyzed. The results found smaller wire sizes could be used. Smaller wire sizes meant smaller conduit could also be used. Other recommendations included using different products that meant easier, faster installation and more readily available products, which led to the savings.

What would make this entry stand out from the rest of the entries when considering MoDOT's practical design philosophy? This was a team approach to looking at the design and construction of a traffic signal overall, rather than project specific, and embodied what practical design is all about. Manufacturers, suppliers and contractors were consulted for cost-saving ideas. The recommendations promote easier, faster installation, and more readily available products. Designers were provided more options and tools to help reduce costs. These changes affect every signal installation thereby promoting consistency in design and construction without compromising safety, operation and maintenance. The savings are repeatable and transferable to others. Cities, counties and developers will benefit from the results as well.