A METHODOLOGY FOR PRIORITIZING SIGNAL STRUCTURAL ASSEMBLY REPLACEMENT

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July 27, 2005
2,713 Words

ABSTRACT OF
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In its FY 2004-2005 budget, the City of Tulsa set dedicated funds for the replacement of a type of signal structural assembly (known as “green arms” because of their color) that are the oldest such assemblies in the city. Because the available funds are not enough to replace the more than 300 “green arms”, a methodology was created to evaluate the green arms and prioritize them. This method involves identifying twenty-two (22) structural deficiencies, and assigning each a unique point value based on that particular deficiency’s effect on the structural integrity of the signal assembly and the related threat to the motoring public. In addition to these structural points, bonus points were given to each “green arm” assembly based on the highest functional classifications of the intersection roadways to help focus financial resources on those locations that are not only a hazard because of structural deficiencies, but also are at a high volume location where the potential for injury to a motorist if the assembly were to fail is the highest. Based on this methodology, every “green arm” assembly was inspected, evaluated, and prioritized, with the top thirty assemblies currently being replaced and a maintenance and inspection program being established to prolong the life of those not currently being replaced.

INTRODUCTION

Traffic signals are an enigma. They are both desired and loathed. They decrease accidents and increase accidents. They are simple and complex. They reduce congestion and increase it. They are inexpensive to install and expensive to operate and maintain. They are thought about and forgotten.

When one speaks of traffic signal operation and maintenance, one is typically referring to phasing, loops, controllers, and bulbs. While the electrical components are indeed the primary maintenance concern, the non-electrical components are important as well. Unfortunately, the non-electrical components, especially the structural components, tend to be ignored with sometimes-catastrophic results.

We have all heard stories about signal structures that have failed and crushed motorists; so have tort attorneys. When such a catastrophe occurs, the government agency responsible for the signal can be liable for millions of dollars, dollars that could have been used for signal maintenance instead of settling a tort claim. Thus, it is imperative for agencies that operate signals to have a program in place to evaluate and prioritize the maintenance of signal structural assemblies.

GREEN ARM REPLACEMENT PROGRAM

Need For Evaluations

Several decades ago, the City of Tulsa, Oklahoma, used salvaged pieces of oil field pipes as signal structural assemblies. Because these structural assemblies were painted green, they became known locally as “green arms”. These assemblies are now nearing the end of their functional lives, and so the city has embarked on a program to replace these “green arms”. However, due to budget limitations, it is not possible to replace all of these arms at the present. Thus, the city created a methodology to evaluate and prioritize the replacement to ensure that the “green arms” that pose the most eminent threat to the safety of the public are replaced first.

Limitations Of Previous Evaluation Methodology

Prior to December 2004, the system used to evaluate the “green arms” involved an inspector giving each “green arm” a grade of A, B, C, D, or F, with “green arms” receiving an F grade being replaced first. In December 2004, this system was thoroughly reviewed for effectiveness, and several significant problems with the system were detected. First, because of the subjectivity of the ratings, a new inspector could not recreate them. What the first inspector found to be a D, the second inspector found to be a B, because there were no clear objective criterion to be used in the evaluation. Second, the same inspector could not recreate the ratings at a later time. The second inspector, as he inspected more “green arms”, changed his grade on several of the assemblies that he had inspected first, which he concluded weren’t as comparatively bad as he initially thought they were. (In other words, when he saw “green arms” that were in even worse shape then the fist ones he saw, he adjusted the ratings and prioritization accordingly.) Third, the system overemphasized superficial problems, such as spotty rust, at the expense of structural problems, such as foundation issues. Fourth, the system did not take into account the probability of a motorist being struck as a result of a “green arm” failure. (For example, two identical “green arms” at two intersections with greatly different volumes were treated exactly the same, even though the probability of a failure causing harm to motorist is less at an intersection with less vehicles.) Finally, the system included city council districts in the prioritization, so that each district would get an equal share of “green arm” replacements. The problem with this balancing is that the bulk of the “green arms” are in two of the nine districts; thus more structural deficient “green arms” were not being replaced while less structurally deficient ones were. After this extensive review, it was decided to put into place an evaluation system that would address these problems.

The Evaluation Elements

Because of their age, the green arms have two structural elements not typically found on modern, galvanized signal mast arm assemblies. The first of these is a two-arm mast arm configuration. (**Figure 1**) Under this configuration, the lower arm serves as a brace of the upper one, resulting in the lower arm being in compression and the upper arm being in tension under a dead load (i.e. only the weight of the signal heads acting on the arms) condition. Because these two arms are subjected to different forces and stresses, defects in each must be noted individually. In other words, to note that there are holes in the mast arm would not be sufficient to adequately evaluate how much these holes compromise the structural integrity of the assembly, as a hole in the compression arm will impact structural integrity differently than an identical hole in the tension arm.

The second atypical structural element is a rib flange at the base of the post. (**Figure 2**) The rib flange is a triangular vertical flange that helps distribute the load from the post into the base flange. Because of these rib flanges, the stresses on any square unit of post surface below the flanges will not be the same as the stresses on an identical square unit of post surface above the flanges. Thus, the need to differentiate between defects to the post located below the rib flanges and defects located above them.

A total of twenty-two structural defects were identified, and an inspection checklist was created to identify which of these defects were present for each green arm. These defects are:

1. Faded paint
2. Missing hand-hole cover
3. Flaking paint
4. Local rust (spots covering less than 50% of the surface)
5. Continuous rust (rust covering greater than 50% of the surface)
6. Assembly leaning
7. Exposure to vehicles (less than 4 feet from the traveled way) (**Figure 3**)
8. Assembly damaged (**Figure 3**)
9. Assembly loose
10. Hole in the bottom of compression arm
11. Hole in the top of compression arm
12. Hole through compression arm (can see completely through arm)
13. Crack in compression arm (greater than 3” long) (**Figure 4**)
14. Hole in tension arm
15. Hole through tension arm
16. Crack in tension arm

17. Hole below rib flange at base of post (**Figure 5**)
18. Hole above rib flange at base of post (**Figure 6**)
19. Hole through post (above rib flange)
20. Crack in post (greater than 3" long above rib flange)
21. Foundation cracked (**Figure 7**)
22. Missing or damaged anchor bolts (**Figure 8**)

In addition to these structural elements, the highest operational functional classification of each of the intersecting streets was also noted. This was done to help prioritize scarce funds towards locations that pose the greatest threat to the safety of the motoring public, namely high volume locations. Unlike a typical planning-based functional classification system, which classifies facilities by how we want them to operate at some future time, an operation functional classification classifies facilities based on how they operate in the present based on speeds, traffic volumes, trip generators, and the quality and availability of existing infrastructure. These functional classifications are as follows:

Class 0 – local street
Class 1 – minor collector (less than 1 mile in length, unstriped, and in residential area)
Class 2 – collector (all striped or unstriped in industrial area)
Class 3 – major collector/minor arterial (less than 5 miles in length)
Class 4 – arterial (more than 5 miles in length or part of arterial more than 5 miles in length or connector to generator of regional importance)
Class 5 – major arterial (more than 5 miles in length)
Class 6 – regional arterial (used for trips of greater than 5 miles and connecting points of regional interest)
Class 7 – freeways (includes ramps)

The Evaluation

Prior to inspection, each green arm assembly was assigned a unique identification number and assigned a coordinate location to allow the inspection information to be geocoded in the future. Green arm assemblies scheduled to be replaced within the next twelve months were discarded from the inspection program, as it was decided that there was no reason to use scarce resources on structures that soon will no longer exist. In order to ensure quality and consistency, two staff traffic engineers performed all inspections, and all data were entered by same. Prior to the inspections, it was estimated that there were 100 green arm assemblies citywide; after the inspections were completed, it was determined that there were 329 green arm assemblies, not including the dozen or so slated for removal and not inspected.

Evaluation Point Values

Initially, all of the structural evaluators were assigned an absolute value between 1 and 20, with the latter being the highest. However, this scheme was abandoned for several reasons. First, the absolute points assigned for each evaluator were subjective and therefore subject to debate. For example, one inspector may consider a hole in the bottom of the compression arm to be worth ten points and another may only consider it to be worth eight. Second, the absolute mathematics was nonsensical. If a hole through a compression arm is considered to be the same as a hole in the bottom and a hole in the top, then logically the point value of a hole through the compression arm is equal to the sum of the values of a hole in the bottom and a hole in the top; however, if the hole in the bottom is worth ten, and the hole in the top is worth twelve, then the hole through is worth twenty-two, which is outside the absolute range.

Because of these shortcomings, the evaluator point values were switched from an absolute value to a relative one, with each evaluator assigned a unique value from one (1) to twenty-two (22), with the point value reflecting the relative importance of that particular evaluator. Thus, the evaluator with a point value of one is the least important and the evaluator with a point value of twenty-two is the most important. The relative values assigned to each evaluator are as follows:

1 Pt	Faded paint
2 Pts	Missing hand-hole cover
3 Pts	Flaking paint
4 Pts	Local rust
5 Pts	Continuous rust
6 Pts	Assembly leaning
7 Pts	Exposure to vehicles
8 Pts	Assembly damaged
9 Pts	Assembly loose
10 Pts	Hole in the bottom of compression arm
11 Pts	Hole in the top of compression arm
12 Pts	Hole through compression arm
13 Pts	Crack in compression arm
14 Pts	Hole in tension arm
15 Pts	Hole through tension arm
16 Pts	Crack in tension arm
17 Pts	Hole below rib flange at base of post
18 Pts	Hole above rib flange at base of post
19 Pts	Hole through post
20 Pts	Crack in post
21 Pts	Foundation cracked
22 Pts	Missing or damaged anchor bolts

As stated previously, because of the scarcity of funds, it is not possible to replace all 329 "green arms" simultaneously. Thus, it is imperative to prioritize which ones have a higher probability of falling on a motorist, those that are not only structurally deficient but also at high volume locations. In order to help achieve this objective, bonus points have been assigned based on the sum of the functional classifications of the intersecting streets. For example, an intersection of a Class 0 facility and a Class 7 facility would receive seven bonus points, zero for the Class 0 and seven for the Class 7. As Tulsa does not have any tri-level freeway-to-freeway interchanges, the maximum amount of bonus points available at any location is thirteen.

Evaluation Results

The maximum number of points available using this relative-value assignment scheme, including bonus points, is 266. The top thirty locations identified in the program are enumerated in **Table 1**, with the green arm with the highest potential for striking a vehicle having the highest point value. As can be seen from **Table 1**, the highest point value is far less than the maximum possible. This does not mean that this mast arm doesn't have numerous defects and isn't a hazard to the motoring public; rather, this means that this mast arm doesn't have every defect, a condition that is purely theoretical and will not exist in actuality. **Table 2** shows the results of the evaluation of the highest-ranking mast arm assembly. As can be seen from this table, this particular assembly has numerous serious structural defects that create a potential for failure, and being at a high volume location, that potential is magnified. Even though this particular assembly does not have all of the possible defects, it does have enough defects to pose a potential threat to motorists and should be replaced.

Based on these rankings, the city has hired a contractor to replace the deficient signal arm structures, of which the top twenty are in the process of being replaced, and assemblies will be replaced in order as the budget allows. For those assemblies that cannot be replaced due to budgetary constraints, a repair, maintenance, and inspection program is being implemented to prolong their lives until such time as they can be replaced.

CONCLUSION

The City of Tulsa's Green Arm Evaluation System is an objective system for prioritizing signal structural replacement, and can be used for any type of signal structural assembly, as some of the evaluators are applicable to any signal structural assembly. For example, for a single arm assembly, the compression arm evaluators would not be used since a compression arm does not exist on this type of assembly. For assemblies without a rib flange at the base of the post, the evaluators pertaining to defects below the rib flange would be ignored. Even if only half of the evaluators are applicable to a particular type of assembly, those evaluators can be used to prioritize all assemblies of that particular type.

In addition to its universal applicability, this methodology yields reproducible results that are independent of the biases of the evaluator. This reproducibility is crucial in ensuring that monies are spent based on objective need and not the subjective desires of the person or persons performing the evaluation.

LIST OF TABLES AND FIGURES

TABLE 1 Top Thirty Green Arm Replacement Locations

Green Arm Scores & Rankings

Total points	Pole	East-West Street	North-South Street	Rank
97	902473	479008O51W	903300HARV	1
87	203392	70230023ST	800700JACK	2
80	902594	567891I44W	903300HARV	3
76	303051	601500PINE	168911GILO	4
75	503144	70460046ST	908100MEMO	5
72	901954	70310031ST	903900NWHV	6
65	502521	479008O51E	906500SHER	7
64	203391	70230023ST	800700JACK	8
63	100021	700000ADMB	901300PEOR	9
62	301054	600000ADMP	906500SHER	10
61	101874	367902244W	900300DETR	11
61	903561	70560056ST	901300PEOR	12
59	101303	601500PINE	900600GRWD	13
58	602584	600000ADMP	911300GARN	14
57	101302	601500PINE	900600GRWD	15
56	401251	70110011ST	902800DELW	16
55	401122	7001001STS	800600GUTH	17
54	303031	60360036ST	903300HARV	18
54	900682	70310031ST	901300PEOR	19
53	102091	700000ADMB	901700UTIC	20
52	301803	601500PINE	904900YALE	21
51	903562	70560056ST	901300PEOR	22
50	100024	700000ADMB	901300PEOR	23
50	102094	700000ADMB	901700UTIC	24
49	402073	7006006THS	901700UTIC	25
48	303074	367902244W	908100MEMO	26
48	400544	7003003RDS	901300PEOR	27
48	403363	70150015ST	800300DENV	28
48	901384	70310031ST	903300HARV	29
47	203393	70230023ST	800700JACK	30

TABLE 2 Evaluation Results For Highest Ranking "Green Arm"

Total points	***97***
Pole #	902473
East-West Street	479008O51W
E-W Functional Classification	7
North-South Street	903300HARV
N-S Functional Classification	5
Total Bonus Points	***12***

Evaluator	Points
Faded	0
Missing Handhold Cover	2
Flaking	0
Local Rust	0
Continuous Rust	0
Assembly leaning	0
Exposure to vehicle	7
Damaged	8
Assembly loose	9
Hole in bottom of compression arm	0
Hole in top of compression arm	0
Hole through compression arm	0
Crack in compression arm	0
Hole in tension arm	0
Hole thru tension arm	0
Crack in tension arm	0
Hole below flange	0
Hole above flange	18
Hole thru post	0
Crack in post	20
Foundation cracked	21
Anchor bolts damaged or missing	0
Total structural points	***85***

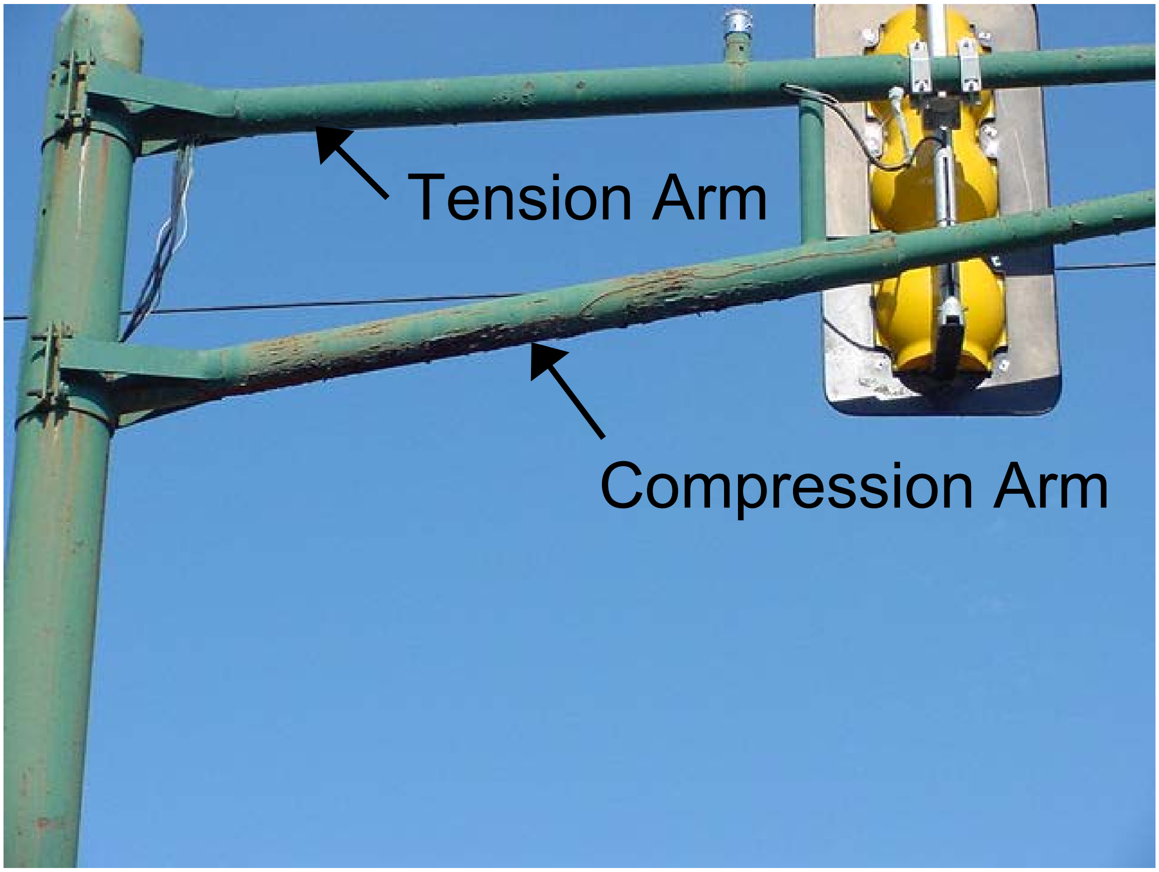

FIGURE 1 Mast arm nomenclature.

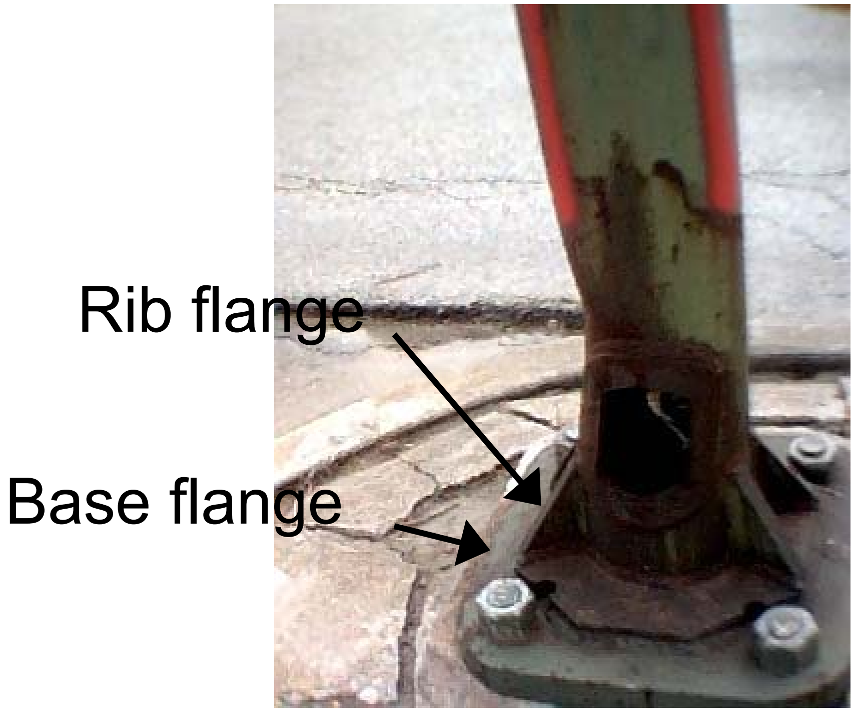

FIGURE 2 Post base nomenclature.

FIGURE 3 Post damaged and in harm's way.

FIGURE 4 Crack in compression arm.

FIGURE 5 Hole in post above rib flanges.

FIGURE 6 Holes above and below rib flanges.

FIGURE 7 Cracked foundation.

FIGURE 8 Missing anchor bolt.