

**Final Report
FHWA Item 4(09)-8(E)
Circular Rapid Flashing Beacons – Santa Monica, CA
April 24, 2013**

Prepared by:

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The City of Santa Monica was granted permission by the California Traffic Control Devices Committee (CTCDC) to experiment with both a Rectangular Rapid Flashing Beacon (RRFB) device and a Circular Rapid Flashing Beacon (CRFB) in March 2011. The experiment with the CRFB was also approved by the Federal Highway Administration (FHWA) on March 11, 2011. Pursuant to the original requests for experimentation, the City is providing this progress report documenting the performance of both devices.

1. Milestones

Both the Rectangular Rapid Flashing Beacon (RRFB) and Circular Rapid Flashing Beacon (CRFB) devices were manufactured by Spot Devices, Inc. The City's Fiscal Year 2011-2012 budget was approved in June 2011 and included funding for the purchase and installation of the new flashing beacon systems. Following the City's official purchasing guidelines, and working with the manufacturer to finalize specific details of both devices, the City received delivery of both devices in October 2011. The devices were installed in November 2011.

Evaluation Locations

The locations for testing the flashing beacons were identified based on the previous evaluation of in-roadway warning light (IRWL) systems. The intersection of Santa Monica Boulevard/Princeton Street previously had an IRWL system installed, and this location was included in the City's IRWL evaluation. After the initial evaluation, the City resurfaced Santa Monica Boulevard, and the City used this opportunity to remove the existing IRWL system and prepare the location for the testing of an alternative device.

Both the CTCDC and FHWA approvals for the City's request to experiment with the new flashing beacons provided for one year of device testing. In order to shorten the testing time frame, the City identified a similar location on Santa Monica Boulevard. With verbal approval from CTCDC members, the City decided to test both devices concurrently at two intersections on Santa Monica Boulevard. Those locations are described in detail below.

Santa Monica Boulevard/Princeton Street



The Santa Monica Boulevard/Princeton Street test site consists of a marked crosswalk on Santa Monica Boulevard across the uncontrolled eastern leg of the intersection. Santa Monica Boulevard is a Principal Arterial. Stop controls are provided on Princeton Street, the minor side street approaches to Santa Monica Boulevard. The

intersection is offset, with the segment of Princeton Street south of Santa Monica Boulevard located approximately 30 feet west of the segment to the north.

Lane Geometrics, Width, and Striping – In the vicinity of the test site, Santa Monica Boulevard has a curb-to-curb width of approximately 68 feet, with five travel lanes (two travel lanes in each direction and a center two-way left turn lane) and two eight-foot parking lanes.

Crossing Enhancements – A high visibility “continental” pattern crosswalk is marked across Santa Monica Boulevard. There are advance “Ped Xing” pavement markings to the east and west of the crossing as well as advance stop bars on both approaches to the crosswalk. On the eastbound approach, the stop bar is located approximately ten feet from the crosswalk. On the westbound approach, due to the offset configuration of the intersection, the stop bar is located approximately 65 feet from the crosswalk. Overhead street lights located on each side of the crosswalk, provide illumination of the crossing at night.

Posted and Prevailing Speeds – The posted speed limit on Santa Monica Boulevard is 30 mph. Observed traffic speeds were considerably higher, in the 35-40 mph range, when traffic streams permitted. The most recent speed survey data indicates the following measured 85th percentile speeds: 32.0 mph eastbound and 31.4 mph westbound.

Sight Distance – Sight distance from the crosswalk was evaluated based on stopping sight distance criteria contained in the Caltrans *Highway Design Manual*, 6th Edition. For the posted 30 mph speed limit, 200 feet is required. Available sight distance for vehicles approaching the crosswalk is adequate in both directions; however, pedestrians standing at the curb waiting to cross the street may be shielded from approaching motorists’ view by parked cars, street signs, and light poles on the eastbound approach. Similarly, on the westbound approach, pedestrians standing at the curb waiting to cross the street may be shielded from motorists’ view by light poles, street trees, and traffic signs.

Traffic Volumes – Traffic counts collected by the City in 2006 indicate Santa Monica Boulevard has an Average Daily Traffic Volume (ADT) of about 28,200 vehicles, with a PM peak hour count of approximately 2,030 vehicles.

Proximity of Existing Traffic Control Devices – Traffic signals are located approximately 725 feet east of the site at Santa Monica Boulevard/Yale Street, and approximately 300 feet west of the site at Santa Monica Boulevard/26th Street.

Adjacent Land Use – Land use in the vicinity of the test site includes strip commercial uses mixed with medium- to high-density multi-family housing developments. Individual land uses include a McDonalds on the southeast corner of the intersection, an auto shop on the northwest corner, auto sales on the northeast corner, and ground floor retail with second story residential on the southwest corner. Steady activity was observed at the automotive site on the northwest corner of the intersection. On several occasions, driveway operations at the site queued into the crosswalk.

Santa Monica Boulevard/Stanford Street

The Santa Monica Boulevard/Stanford Street test site originally consisted of unmarked uncontrolled crosswalks on Santa Monica Boulevard. Santa Monica Boulevard is a Principal Arterial. Stop controls are provided on Stanford Street, the minor side street approaches to Santa Monica Boulevard.

Lane Geometrics, Width, and Striping – In the vicinity of the test site, Santa Monica Boulevard has a curb-to-curb width of approximately 68 feet, with five travel lanes (two travel lanes in each direction and a center two-way left turn lane) and two eight-foot parking lanes.

Crossing Enhancements – A high visibility “continental” pattern crosswalk was installed across Santa Monica Boulevard for the purposes of this experiment. Advance stop bars are provided on both approaches to the crosswalk. On the eastbound approach, the stop bar is located approximately on the adjacent side of the intersection from the crosswalk. On the westbound approach the stop bar is located approximately 10 feet from the crosswalk. Overhead street lights located on each side of the crosswalk, provide illumination of the crossing in the dark.

Posted and Prevailing Speeds – The posted speed limit on Santa Monica Boulevard is 30 mph. Observed traffic speeds were considerably higher, in the 35-40 mph range, when traffic streams permitted. The most recent speed survey data indicates the following measured 85th percentile speeds: 32.0 mph eastbound and 31.4 mph westbound.

Sight Distance – Sight distance from the crosswalk was evaluated based on stopping sight distance criteria contained in the Caltrans *Highway Design Manual*, 6th Edition. For the posted 30-mph speed limit, 200 feet is required. Available sight distance for vehicles approaching the crosswalk is adequate in both directions; however, pedestrians standing at the curb waiting to cross the street may be shielded from approaching motorists’ view by parked cars, street signs, and light poles on the eastbound approach. Similarly, on the westbound approach, pedestrians standing at the curb waiting to cross the street may be shielded from motorists’ view by light poles, street trees, and traffic signs.

Traffic Volumes – Traffic counts collected by the City in 2006 indicate Santa Monica Boulevard has an Average Daily Traffic Volume (ADT) of about 28,200 vehicles, with a PM peak hour count of approximately 2,030 vehicles.

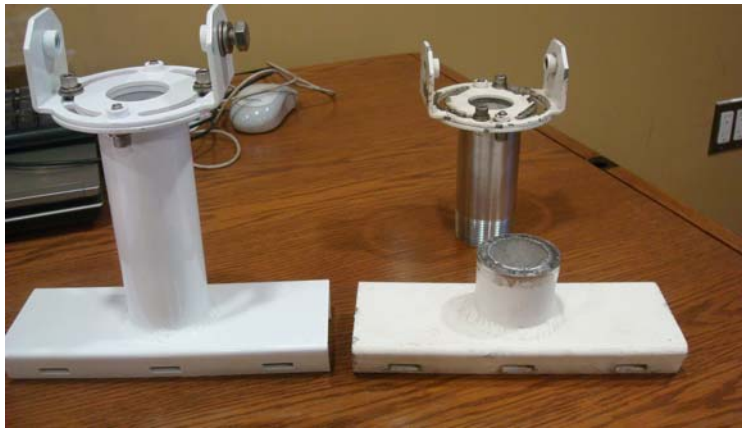
Proximity of Existing Traffic Control Devices – Traffic signals are located approximately 300 feet west of the site at Santa Monica Boulevard/Yale Street, and approximately 725 feet east of the site at Santa Monica Boulevard/Berkeley Street.

Adjacent Land Use – Land use in the vicinity of the test site includes strip commercial uses mixed with medium- to high-density multi-family housing developments. Individual land uses include a medical equipment vendor on the southeast corner of the intersection, a small commercial shopping plaza on the northwest corner, a hotel on the northeast corner, and an automotive sales facility on the southwest corner.

Pre-Deployment Device Preparation

Following delivery of the new devices in October 2011, staff from the City's Traffic Signals Section made a number of modifications to the beacon mounting systems. These modifications were made to ensure that the devices would be fully adjustable once installed on traffic signal poles. The modifications allowed for each beacon device to be adjusted so that the beacons would face the desired path of travel. The modifications were made using available equipment in the Traffic Signal Shop, and were documented for future applications.

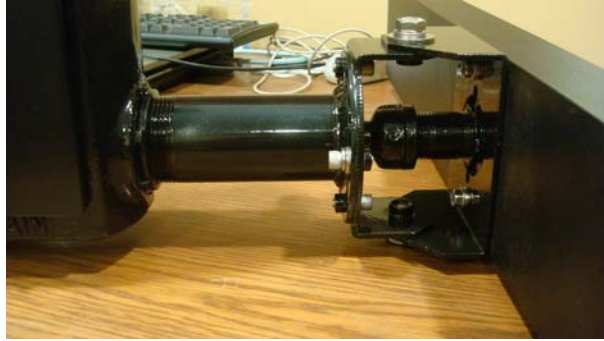
The City of Santa Monica made many after-market modifications to the RRFB device as provided by the manufacturer. The RRFB housings were initially designed to be attached to a pole directly. City staff created modified mounts for the housing using video detection equipment mounts.



The modified mounts are affixed to a standard terminal block, and allow the RRFB housings to be angled towards or away from the roadway, and rotated from top to bottom.



Here is another view of the RRFB housing mounts, showing the adjustable angle of the RRFB. This mounting ensures that once the RRFB is affixed to the pole, the RRFB housing can be angled to point directly at the path of travel of oncoming vehicles.



Below is an image of the finished modification, with the terminal block holding two RRFB housings, to face each direction of oncoming traffic.



Last is an image of the finished devices mounted to a pole. Once mounted, the fully adjustable mounting allowed for optimal adjustment to aim the flashing beacons at oncoming traffic.



Similar modifications were made to the CRFB device. Each of the circular indications was mounted on standard traffic signal installation housings, and attached to the pole via a terminal block.



The modifications allowed each of the circular indications of the CRFB to be directed towards oncoming traffic.



Deployment

The photos below show the flashing beacon systems as installed. The first photo shows the RRFB at the intersection of Santa Monica Boulevard/Princeton Street, while the second photo shows the CRFB at the intersection of Santa Monica Boulevard/Stanford Street.



In May 2012 the locations of the two devices were swapped, with the RRFB moved to Santa Monica Boulevard/Stanford Street and the CRFB moved to Santa Monica Boulevard/Princeton Street.

In November 2012 the locations of the two devices were again swapped, with the RRFB moved back to Santa Monica Boulevard/Princeton Street and the CRFB moved back to Santa Monica Boulevard/Stanford Street. At this time the back plates on the CRFB were removed and back plates were added to the RRFB.

Evaluation

Data collection was conducted to determine driver reactions to a pedestrian showing an intention to cross the street. The purpose of the tests was to document behavior exhibited by motorists approaching crosswalks both with and without the R/CRFB in operation to determine if the devices are effective in increasing the awareness of drivers. Data collection for the “with R/CRFB” conditions began in January 2012, and a second set of data was collected in May 2012. A third and final set of data was collected in November 2012. For the third set of data, back plates were added to the RRFB device and were removed from the CRFB device, in order to determine if the presence of back plates affected driver yielding response. The purpose of switching the locations of the two devices and adding and removing back plates to the devices was to evaluate variables related to device location and construction.

A team of two technicians was utilized to record the observations with one technician acting as the “staged pedestrian.” To be inconspicuous to motorists during the testing process, the pair wore plain clothes, communicated via hand held radios, and the observer recorded test data from a vantage point outside of the driver’s peripheral vision. Evaluations were performed during weekday conditions only. Five test sessions were performed at each location, including three during daylight hours, one at dusk, and one at night. The day sessions were conducted in the morning between 9:00 AM and 11:00 AM, mid-afternoon between 12:00 PM and 2:00 PM, and late afternoon between 2:30 PM and 4:00 PM. Dusk sessions were recorded during the lighting transition from daytime to nighttime, which typically occurred between 4:30 PM and 6:00 PM. Night sessions were recorded when there was no ambient sunlight, between 6:30 PM and 8:00 PM. Each testing session consisted of a minimum of 40 pedestrian crossings, including 20 observations of traffic in each direction. For each of the 20 directional crossings, testing was further broken down with ten observations recorded with the R/CRFB system on, and ten observations with the R/CRFB system off.

The following behaviors for the primary vehicle (closest vehicle to the crosswalk) were observed and recorded:

- Drivers that yielded or did not yield to pedestrians
- The distance in advance of the crosswalk at which drivers first applied their brakes
- The location at which drivers stopped to yield to pedestrians
- The number of drivers that attempted to pass a stopped or yielding vehicle
- The number of drivers that braked abruptly

Behaviors were also observed for secondary vehicles approaching in the adjacent lane, including whether or not the driver of the secondary vehicle yielded, braked abruptly, and the distance at which this occurred.

Yielding Observations

An approaching motorist was recorded as yielding to a pedestrian if he or she slowed or stopped and allowed the pedestrian to cross. Motorists were recorded as not yielding if he or she passed in front of the pedestrian but would have been able to stop for the pedestrian based on the signal timing parameters published by the Institute of Transportation Engineers (ITE). The ITE formula used to determine the duration of the yellow clearance phase for traffic signals was applied as this formula takes into account driver reaction time, deceleration rates, posted speed limit, and roadway grade in order to determine the distance that is required for a driver to stop safely for a traffic signal that turns red. This concept can similarly be applied to that of a driver yielding to a pedestrian in a crosswalk.

In order to observe yielding distances, measurement markings were applied to the roadway in advance of the test crosswalks. Measurement markings were painted at 50-foot intervals beginning at the stop bar (referred to as 0 feet) and extending to the distance determined through use of the ITE signal timing formula. The recorded data also included the lane the driver was traveling in. For data collection purposes, the lane closest to the sidewalk was designated as Lane #2, while Lane #1 was closest to the centerline/median. The data collected and used for analysis only refers to the reaction of the driver of the primary vehicle.

Pedestrian crossings were staged utilizing specific protocol to ensure the consistency of collected data. Hand held radios were used by the observer and the acting, or 'staged,' pedestrian to communicate when a vehicle was approaching the dilemma zone threshold, which was demarcated by a line painted across the travel lanes. At the instant the vehicle crossed this mark the staged pedestrian entered the crosswalk and/or activated the system. If other vehicles pulled out of side driveways, maneuvered to make a turn, or if an unforeseen condition occurred that could alter driver behavior, the staged crossing was voided and no data was collected. Once the intersection was cleared and conditions fit the protocol, the team would resume the data collection process. Drivers that entered the dilemma zone under ideal conditions had adequate time to stop safely, so were counted and scored as either yielding or not yielding.

Yielding Distance

Two measurements were recorded for vehicle yielding distances. First, the observer recorded the distance at which drivers reacted to the activated IRWL system and/or the test pedestrian by applying their brakes. Second, the test pedestrian noted the actual distance at which the motorist yielded in advance of the crosswalk. The primary measurement used for this evaluation was the initial breaking reaction by drivers, which demonstrated a response to either the crosswalk warning system or the test pedestrian. While the ultimate distance from the crosswalk at which drivers yielded is meaningful and has safety implications, motorists' initial braking reaction was utilized for this

evaluation as the primary distance measure since it is a definitive occurrence compared to the more subjective 'yield' distance.

Driver Passed or Attempted to Pass Stopped Vehicle

A vehicle was recorded as passing, or attempting to pass, if the driver changed lanes to pass a vehicle that was yielding to a pedestrian in the crosswalk. This action is an offense under the California Vehicle Code which states in Section 21951: "Whenever any vehicle has stopped at a marked crosswalk or at any unmarked crosswalk at an intersection to permit a pedestrian to cross the roadway the driver of any other vehicle approaching from the rear shall not overtake and pass the stopped vehicle."

Sudden Braking

A driver was recorded as braking suddenly if the front-end of the vehicle was observed dipping sharply toward the ground.

2. Status

Evaluation Results

The table on the following page presents a summary of the evaluation results for both devices during the two initial evaluation periods. As noted previously, for the May 2012 data collection efforts the locations of the two devices were swapped, and in November 2012 the locations were again swapped and back plates were removed from the CRFB and added to the RRFB device.

In general both devices showed increases in driver yielding response rates when activated, except in one situation during the January 2012 evaluation.

From the field evaluations in January 2012, it is unclear what caused the decrease in driver yielding response rates for the RRFB during the dusk evaluation. The detailed evaluation data shows that the decrease in yielding response rates occurred only in the westbound direction on Santa Monica Boulevard, and the eastbound direction actually showed no change in yielding response rates whether the RRFB was activated or not (90% for both states of operation). Therefore, it is the opinion of the author that glare from the sunset at dusk was perhaps a factor in the reduction in driver yielding responses. Further evaluations in May and November did not show the same reduction in yielding response rates; therefore, the author concludes that the January results were an anomaly.

Summary of R/CRFB Evaluations

Location:		Santa Monica/Princeton	Santa Monica/Stanford	Santa Monica/Stanford	Santa Monica/Princeton	Santa Monica/Princeton	Santa Monica/Stanford
Device:		RRFB	CRFB	RRFB	CRFB	RRFB ¹	CRFB ¹
Time of Day	State of Operation	January 2012		May 2012		November 2012	
		Yielding Response (Approx.)		Yielding Response (Approx.)		Yielding Response (Approx.)	
Day-time	Off	73%	83%	58%	57%	60%	83%
	On	85%	92%	80%	63%	78%	92%
	Change	+12%	+9%	+22%	+6%	+18%	+9%
Dusk	Off	85%	75%	65%	20%	40%	35%
	On	80%	100%	85%	55%	80%	60%
	Change	-5%	+25%	+20%	+35%	+40%	+25%
Night	Off	60%	80%	35%	35%	40%	35%
	On	95%	90%	80%	65%	65%	70%
	Change	+35%	+10%	+45%	+30%	+25%	+35%

Note: 1. In November 2012, the back plates were removed from the CRFB devices and new back plates were fabricated for the RRFB devices.

It was interesting to observe that yielding response rates during all evaluations were generally higher at the intersection of Santa Monica Boulevard/Stanford Street than at the intersection of Santa Monica Boulevard/Princeton Street. This may be due in part to the sidewalk width near Princeton Street and the adjacent land uses. Although both locations are similar in cross-sectional roadway width, traffic volumes, and proximate traffic signals, the intersection with Princeton Street has a proximate signal to the west while the intersection with Stanford Street has a proximate signal to the east. Traffic flows are generally higher in the westbound direction, particularly during the afternoons, and this results in substantial queues of traffic backing up into the intersection with Princeton Street. These factors – sidewalk width and heavy traffic volumes – may cause a reduced ability for motorists to see pedestrians attempting to use the crossing. Even when the specific devices were switched between locations, the yielding response rates at Santa Monica Boulevard/Stanford Street generally remained higher.

The May 2012 evaluations were generally consistent with the January 2012 evaluations in that both devices showed increases in driver yielding response rates when activated. Driver yielding response rates when the devices were not activated were significantly lower during the May 2012 evaluations. The evaluations also show that overall driver yielding response rates, with the device activated or not, were substantially reduced at the intersection of Santa Monica Boulevard/Princeton Street when the CRFB was installed.

The final evaluations in November 2012 were also generally consistent with previous evaluations. Even with back plates removed from the CRFB and added to the RRFB, both devices showed increases in driver yielding response rates when activated.

Conclusions

The evaluation results generally show that both flashing beacon systems increase driver yielding response rates. The RRFB seems to result in a greater increase in driver yielding response than the CRFB, with about a 24% average increase for the RRFB versus an about 20% increase for the CRFB.

The reports from the data collection team during the January 2012 evaluations indicate that amongst drivers who saw the pedestrian attempting the crossing, the flashing beacons seemed to legitimize the pedestrian crossing, and that drivers seemed to feel more compelled to let the pedestrian cross when the flashing beacons were activated rather when they were not activated. During the May 2012 evaluations, field observations suggest that drivers were generally much more aggressive than in the previous evaluations, and in November 2012 driver behavior had calmed from May 2012 levels.

Several trends were found to persist during both evaluations:

1. Neither device appeared to have any effect on yielding distance.
2. During daytime sessions, data suggests that the rectangular beacons are more effective than circular beacons in improving crosswalk compliance, with an average yielding response increase of 17%.
3. During dusk sessions, data suggests that the circular beacons are more effective than rectangular beacons in improving crosswalk compliance, with an average yielding response increase of 28%.
4. During night sessions, data suggests that rectangular beacons are more effective than circular beacons in improving crosswalk compliance, with an average yielding response increase of 35%. Field observations suggest that the rectangular beacons were brighter and more visible at night than the circular beacons.
5. The locations of the devices seemed to have some effect on yielding response rates; however the evaluation data is not clear as to the extent of the effects. Similar to any other traffic control device, the City recommends future decisions to install C/RRFB devices should carefully consider all factors and field conditions in accordance with the California Manual on Uniform Traffic Control Devices.
6. The presence of back plates does not appear to have a significant effect on yielding response rates for the rectangular beacons, with rates in the 80% range both with and without back plates (Note: the November 2012 data did show a significant reduction in yielding rates; however, the data still showed an increase of 25% when the device was activated).
7. Overall, the RRFB appears to have the greatest positive impact on driver yielding response rates during all time periods. The functionality of the device, coupled with its minimal design and overall effectiveness, indicates that this device would be a welcome addition to the toolbox of available pedestrian crossing enhancements.

3. Summary of Experiment

The City of Santa Monica appreciates the opportunity to perform this valuable experiment. The experiment results indicate that the RRFB would be a welcome addition to the toolbox of available pedestrian crossing enhancements. The data also shows that the CRFB is a viable alternative to provide similar enhancements for pedestrian safety.

The CRFB device was custom fabricated for the purposes of this experiment, and was found to be effective. However, the RRFB was found to have the best overall performance in terms of increasing driver yielding response rates. Therefore, the City

believes that this evaluation clearly indicates that the rectangular shape of the RRFB beacons is an important factor of its overall performance as a traffic control device.

Should you have any questions or require any additional information, please contact me directly.

Respectfully,

A handwritten signature in black ink, consisting of a series of loops and a long horizontal stroke extending to the right.

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