A FORENSIC ENGINEERING ANALYSIS OF PEDESTRIAN TRIPS AND FALLS SUBJECT TO WHEELSTOPS IN PARKING LOTS

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Abstract

A forensic engineering analysis of wheelstops (wheel stops, parking bumpers, curb stops, etc., by any other name) reveals such devices are unnecessary and potentially hazardous to pedestrians when wheelstops are installed within parking lots, of which wheelstops are the direct cause of numerous pedestrian trips, falls, and subsequent injuries. Wheelstops are rarely (if ever) needed for the effective design of parking lots and can be eliminated entirely (especially within or near pedestrian pathways), and when desired, replaced with considerably safer site elements.

It is important to note that the design of parking lots must not only provide for the vehicular path of cars and trucks and a sufficient amount of parking spaces, but also for safe and inevitable pedestrian traffic. It is further imperative to emphasize vehicular and pedestrian traffic are competing elements. Accordingly, for safety reasons, many times a pedestrian will avoid walking within a designated travel lane. Instead, opting for paths between parked vehicles. Therein lies a significant conflict which often results in the pedestrian's trip, fall, and injuries.

The initial purpose of this research is to present a statistical evaluation of wheelstops in the parking lots of various commercial locations throughout much of the United States, as found along a major East-West route, from coast to coast through many major cities. This extensive study will then present improved and beneficial site design techniques and will reveal authoritative sources regarding the ill-advised use of wheelstops and the referenced improvements.

This study in pedestrian safety will result in providing the forensic Engineer with credible published and authoritative sources regarding the hazards of wheelstops and recommended alternatives.

Keywords

Forensic Engineering, wheelstops, wheel stops, parking bumpers, curb stops, pedestrian accident(s), parking stall(s), numerical sampling, statistical analysis, visual acuity, accessible

INTRODUCTION

Scenario 1: A disabled man and his wife departed from the elevator lobby of a hotel and walked up an incline to their parked rental car, located in an accessible (i.e., handicap) parking

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stall. The gentleman held the passenger door open for his wife's entry into the vehicle. He then walked around the front of their car; however, when he turned to access the driver side door, he tripped over a non-painted 6' long concrete wheelstop which protruded 2' into the access aisle located between two accessible parking spaces. The man, recovering from a prior and significant Achilles heel injury and surgery, re-injured the initial injury which required additional surgeries.

Scenario 2: A lady shopper returned to her parked car from a "big box" store. She loaded her purchases into her car and returned her shopping cart to a nearby cart corral. Upon her return, she reached the front of her car when she tripped over a wheelstop and fell forward, wherein she sustained significant injuries. The wheelstop had been placed across the common painted stall line between two adjacent parking stalls.

The first case occurred during daylight hours but inside a parking garage where light levels were minimal, due somewhat by the shadows from parked cars. The second case took place outdoors during the daytime when bright daylight conditions existed. While ambient lighting conditions are often relevant, this report will stress strictly the hazardous nature of wheelstops within pedestrian pathways such as presented in these two scenarios without relevance to ambient lighting.

The two referenced examples illustrate typical trip/falls over wheelstops placed within predictable pedestrian paths. Such installations are hazardous, unnecessary, and can functionally be eliminated altogether. In addition, wheelstops often become dislodged or broken, leaving debris and exposed rebar within a pedestrian's path.

While there are publications and some local standards which appear to recommend the placement of wheelstops, there are also numerous and credible sources which recommend against their use. Said publications will be addressed within this document and may be found in the final section of this report, "References."

The following commentary shall serve to (1), address the trip/fall potential caused by wheelstops (2), present a representative and quantitative evaluation of wheelstop locations and (3), recommend alternative designs.

WHEELSTOP PARAMETERS

Wheelstops are essentially physical barriers intended to halt the movement of a parking vehicle beyond design elements for the parking stall; however, they often do not provide this desired function and are often unnecessary. Serious injuries to shoppers and other pedestrians can result from the presence of wheelstops. In addition, extensive property damage is not an uncommon consequence of vehicles accidentally mounting and driving over wheelstops. There are, however, safer alternatives.

It has been a relatively common practice in recent years to provide wheelstops within parking lots, especially in critical areas such as accessible parking stalls. (Note the term "accessible" is considered somewhat synonymous with the word "handicap"; however, the Federal government prefers to not recognize the term "handicap" as such a term infers a negative "disability" or "lack in ability" to perform any of life's critical functions. As such, this report will use the term "accessible" or "accessibility" in conformance with Federal terminology.)

Wheelstops are often installed for the purpose of stopping the forward movement of vehicles and for protecting sign posts such as installed at the front of accessible parking stalls. However, vehicle designs vary. Some are designed for a long overhang in the front and some in the rear. Smith and Carwile[1] offers, "Further, many automobiles have cowls under the front bumper that can be damaged by striking the wheel stop." They also offer the following critical observation regarding pedestrian safety:

> *However, the most important concern regarding wheel stops is the risk of trips and falls. Concrete wheel stops are extremely difficult to see against concrete, as shown in Figure 13-36* **[not included herein]**. *Painting them traffic yellow is strongly recommended if they are provided, but it becomes an ongoing maintenance issue. Additional problems with wheel stops include the difficulty of securely anchoring them to the surface, so they are not pushed out of position through repeated bumps. It is difficult to clean behind wheel stops. When mechanically anchored (whether epoxied to the surface or bolted down), they often damage the floor slab over time and may eventually break loose. These problems are exacerbated in the snow belt, not only because of plowing, but also because salt conditions accelerate deterioration of damaged concrete*[2].

Finally, the Smith and Carwile source recommends that, for the safety of pedestrians, wheelstops should be avoided and only used as curbs and curb islands along the perimeter of a parking lot, to protect stairs, elevators, walls, and landscaping although they further suggest, as is supported within this project, the substitution of bollards (discussed in a subsequent section).

Wheelstops are often precariously and needlessly located not only in the front-center of parking stalls but also in hazardous positions, such as across the common line between two adjacent parking stalls or to an extreme side of a parking stall which jeopardizes pedestrian safety when walking between two parked vehicles. (It is not uncommon for a property owner/manager to claim something like, "It was just as effective to place a single wheelstop across the common line between two adjacent parking stalls.")

Many governmental entities (cities, counties, etc.) do not require the installation of wheelstops. Some, however, have predominately zoning standards which require wheelstops along lot perimeters–an outdated standard, and/or where a vehicle encroaches upon a parking stall where the car or truck faces the building An excellent "standard of the industry" for the use/non-use of wheelstops may be found in ASTM standard F1637.

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[1] Smith, Mary S., PE; Carwile, Randall W., PE, Traffic Engineering Handbook, Seventh Edition, Chapter 13, Institute of Transportation Engineers, Pande, Anuag, PhD & Wolshon, Brian, PhD, PE, PTOE, Co-editors, John Wiley & Sons, Inc., Hoboken, New Jersey, 2016.

[2] Ibid.

ASTM International (formerly American Society for Testing and Materials) provides walkway safety criteria in ASTM Stnd. F1637. A critical section of that standard emphasizes the need for pedestrian safety regarding the placement of wheelstops. Essentially, the standard recommends against the use of wheelstops in pedestrian areas; however, when used, the ASTM recommends specific location and visual elements. An excerpt from ASTM Stnd. F1637 is as follows:

> **9. Wheel Stops**
> 9.1 Parking lots should be designed to avoid the use of wheel stops.
> 9.2 Wheel stops shall not be placed in pedestrian walkways or foreseeable pedestrian paths.
> 9.3 Wheel stops shall be in contrast with their surroundings.
> 9.4 Wheel stops shall be no longer than 6ft. (1.83 m) and shall be placed in the center of parking stalls. The minimum width of pedestrian passage between wheel stops shall be 3 ft. (0.91 m).
> 9.5 The top of wheel stops shall not exceed 6.5 in. (165 mm) in height above the parking lot surface.
> 9.6 Adequate illumination shall be maintained at wheel stops as governed by the requirements of local codes and ordinances or, in their absence, by the recommendations set forth by the Illuminating Engineering Society of North America (IES-Application and Reference Volumes).
> 9.7 Bollards, not less than 3 ft. 6 in. (1.07 m) height, may be placed in the center of parking stalls as an alternative to wheel stops. Bollards should be appropriately marked to enhance visibility.

Various materials are used in the production and placement of wheelstops including concrete, rubber, fiber-resins, and railroad ties; however the most common material appears to be concrete. A typical configuration is revealed in Figure 1 and Exhibit 1 (attached) wherein rebar (or spikes) are inserted into holes near each end of the wheelstop and into the parking lot surface (and beneath). Alternative means of attempting to secure the installation may also include epoxy. A typical precast concrete wheelstop is 6' long as represented in the following Figure 1 and Exhibit 1 extracted from a public standard (location redacted).

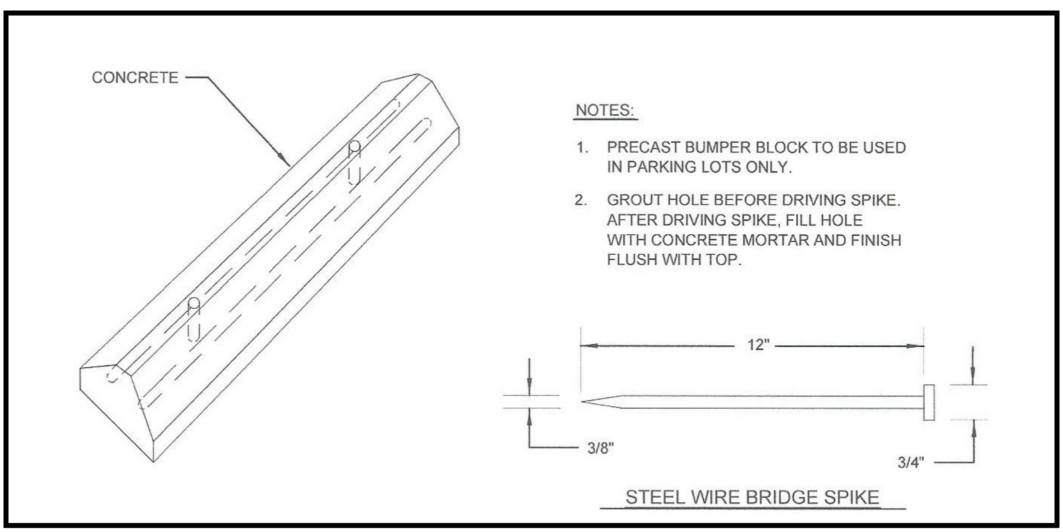

Figure 1: Typical concrete wheelstop.

However, the concrete wheelstop often develops cracks at or near the location of rebar (or spikes) where in time the concrete eventually fails and leaves debris and on occasion, exposed rebar, both recognized tripping hazards. Essentially, as a vehicle's tire impacts the wheelstop near the rebar, the force results in a material stress of which the concrete eventually fails, initially leaving cracks wherein the concrete ultimately breaks leaving debris and often, exposed rebar. Initially cracks appear within the concrete in the area of rebar (or spikes). The cracks typically expand upon receiving additional "bumps" from the wheels of parked cars and eventually, the concrete fractures, leaving debris such as rocks and remnants of concrete, in the area of pedestrian traffic which results in additional sources of trip and fall hazards. (Note Photo Ex. 1.)

Photo Ex. 1: Note fractured wheelstop.

Wheelstops within parking lots are also subject to impact by street sweepers, snow removal machinery, and delivery vehicles or by other means which, when wheelstops are not properly secured, they are occasionally displaced. This is often a common effect of snow removal in locations where the wheelstop boundaries are often not seen. (See Photo Ex.2.)

Photo Ex. 2: Note displaced wheelstops.

QUANTITATIVE STUDY

In the course of this research, a "digital journey" beginning in Baltimore, Maryland was completed. The "journey" required viewing (via Google Earth), various commercial facilities in order to (1) count the number of parking spaces, (2) count the number of accessible spaces, (3) count the number of wheelstops, and (4) noting any unique wheelstop installations (e.g., those which would typically be beyond normal pedestrian paths, such as landscape elements and lot perimeters). The "journey" began on the east coast (Baltimore, MD), and continued along Interstate 70 to western Utah then along Interstate 15, ending in Los Angeles, California. The "stops" began in Baltimore, MD continuing on to Philadelphia, PA, Cleveland, OH, Indianapolis, IN, St. Louis, MO, Kansas City, MO, Denver, CO, Las Vegas, NV, ending in Los Angeles, CA.

Numerous parking lot locations were analyzed in each of nine cities. An attempt was made to review small parking lots (up to and including 100 spaces), medium lots (from 101 to 200 spaces), and large parking lots (over 200 spaces). We found a general consistency in parking lot design and the use of wheelstops; however, we also found some "outliers" which were not typical and removed from our study. Those outliers were rare locations where there were either no wheelstops, a wheelstop placed in every parking stall, or some other unique condition. The outliers were eliminated for our study, the primary purpose of which was to analyze and compare "typical" parking lots found throughout the "I-70/I-15" corridor.

In each city, beginning with the easternmost city of Baltimore, Maryland, a representative sampling of small, medium, and large parking lots was made (as referenced in the prior paragraph). Of those, the number of parking stalls through each parking lot was obtained as was the number of wheelstops throughout each facility. The number of wheelstops used in perimeter areas such as property boundaries and landscape elements were then eliminated in order to assess the number of those wheelstops strictly within areas of expected pedestrian traffic. The number of accessible parking stalls were evaluated in addition to those which contained wheelstops.

This study was performed by utilizing the “Google Earth” computer program which first revealed obvious parking facilities along the I-70/I-15 corridor. Upon selecting (at random), various parking lots for study, each outdoor parking lot was evaluated based on its “typical” configuration wherein the “outliers” were eliminated as presenting a bias to the purpose of the study.

Google Earth allowed a “closeup” view of each parking facility wherein each space was counted and observed for the quantity of parking stalls, accessible spaces, and number of wheelstops. Occasionally, the referenced program would allow a “virtual drive” through much of the parking lots wherein many individual stalls were closely observed and evaluated.

The following represents the results of the analysis. Note, in accordance with NAFE (National Association of Forensic Engineers) guidelines regarding the technical content of reports, the names of each location studied are not revealed herein. Essentially, big box store parking lots were evaluated, as were those of local pharmacies, gas stations, strip malls, schools and churches, restaurants and other facilities. The following chart (Figure 2), represents a sampling of parking lots.

QUANTITATIVE ANALYSIS OF PARKING LOTS			
City, State	**Total No. Parking Spaces**	**Total No. Accessible Parking spaces**	**Total Number Wheelstops***
Baltimore, MD	1119	30	3
Pittsburg, PA	1104	38	50
Columbus, OH	1352	34	21
Indianapolis, IN	1509	58	15
St. Louis, MO	886	35	52
Kansas city, MO	849	34	127
Denver, CO	961	28	87
Las Vegas, NV	1037	34	99
Los Angeles, CA	707	30	17
Total	**9,524**	**321**	**471**

Figure 2.

* Total number of wheelstops within pedestrian pathways, excluding perimeter wheelstops.

This study revealed out of 9,524 parking spaces, only 471 contained wheelstops (4.9%) within pedestrian paths of travel. This figure appears to contradict any potential claim that wheelstops are common elements in parking lots and proves parking lots may be designed, constructed, and maintained without wheelstops.

In an attempt to validate the "I-70" study further, the research was expanded into four additional locals, each of which had no direct proximity to the chosen east-west route. Additional parking lot parameters were accessed and evaluated in Seattle, WA, Chicago, IL, Houston, TX and Jacksonville, FL. This expanded the number of parking stalls reviewed from 9,524 to 15,034 of which only 3.7 % included wheelstops within possible pedestrian pathways (as opposed to the initial I-70 study resulting in 4.9 %).

HUMAN FACTORS

The field of human factors is not intended to be thoroughly discussed within this study except to recognize the typical visual pattern of a pedestrian. Also, lighting conditions often affect the conspicuity of a wheelstop, especially when walking between parked vehicles which often cast shadows. For this reason, highly contrasting colors (e.g., traffic yellow) should be painted on wheelstops. Adequate ambient lighting is often lacking in wheelstop locations, especially when the light provided by pole-mounted lights is restricted by shadows of parked cars.

There is often a claim that the wheelstop was "open and obvious" and that the shopper/pedestrian should have watched where they were walking. The defect in this logic is that pedestrians typically look toward their objective and scan the surrounding terrain. People simply may only occasionally glance down at their feet, an improbable feat especially when carrying packages.

ALTERNATIVE DESIGNS

Local Standards

Some local and zoning ordinances require wheelstops to be placed parallel to a building wall when an adjacent sidewalk is 7 ft. (varies) or less. The premise is that wheelstops will stop an errant vehicle from encroaching onto the sidewalk and into the side of the building or into the path of a pedestrian. An article written by traffic consultant Paul C. Box and published in the May, 1997 edition of Public Works magazine disputes this fallacy wherein Mr. Box states,

> *When parking is allowed nose in to a building and pedestrian access is allowed along that side, it is common practice to utilize a raised walk next to the building. This walk should be at least 5 ft wide and preferably 6 to 7 feet wide to allow space for bumper overhang as well as for pedestrian use. With such conditions, and assuming a height of about 5 in. or more, there is no need for wheelstops. It is true that a careless driver can mount the curb (at only five mph) and strike the*

building or a pedestrian on the walk.[3]

This author's professional experience and testing of such claims, confirms Mr. Box's opinions.

Essentially, wheelstops do little to halt an errant vehicle at speeds of five mph or greater. Wheelstops such as that shown in Figure 1, often have a sloped surface on each side. As such, a vehicle's tire may strike the sloped wheelstop surface which acts as a ramp, vaulting a moving vehicle upward wherein no "halting" mechanism is provided. Additionally, the larger the tire, the greater propensity for a vehicle to "ride over" a wheelstop.

Local standards would best be served by prohibiting parking designs wherein a parking stall places a vehicle in the direction of narrow sidewalks and/or buildings. Alternative designs may suggest guardrails with intermittent openings for pedestrian access.

Bollards

As stated in ASTM F1637, bollards are a reasonable and preferred alternative to wheelstops. Bollards will stop an errant vehicle where wheelstops and sign posts will not. Since Federal (ADA) and many local standards for parking lot design, require accessible signage to be placed at certain heights (5' to the bottom of signs required by the ADA), and in the front of accessible parking stalls, the preferred and safe design would include the elimination of wheelstops, and the replacement of concrete-filled steel bollards with the required signage affixed atop the bollard (see Photo Ex. 5).

A major hotel and recreational facility experienced civil litigation regarding a trip and fall wherein an elderly lady stepped off a raised curb (from an established pathway leading to her parked car) and onto an asphalt parking lot. She then proceed to walk toward her parked vehicle located within an accessible parking stall. As the legal discovery process went on, it was revealed by management personnel that wheelstops were initially installed to protect signposts supporting ADA-required accessability sign placed atop the signposts. Evidence of the failure to protect the signposts are presented herein as Photo Ex. 3.

In addition, a frontal view of the same location reveals the mis-placed wheelstops, placed to one side of the parking stall and near an expected pedestrian pathway where the elderly lady tripped over a wheelstop and sustained significant injuries (see Photo Ex. 4).

Finally, a solution was presented (via Windows Paint) which effectively addressed the errors in judgement and settled the civil suit (see Photo Ex. 5).

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3 Box, Paul C., Public Works, May 1997, Vol. 128, p64

Photo Ex. 3. Note leaning sign posts.

Photo Ex. 4. Off-center wheelstops created tripping hazard.

Photo Ex. 5. Wheelstops removed and signs placed atop concrete-filled steel bollards.

CONCLUSION

Wheelstops are hazardous elements when placed within predictable pedestrian paths in parking lots. Such elements are not necessary since the overwhelming number of parking stalls can be delineated solely by painting each parking stall boundary (ref. Photo Ex. 5). The ADA Accessibility Guidelines require that accessible parking stalls (i.e., those for disabled persons), require accessibility signs be placed a minimum of 60" above the surrounding grade to a point at the bottom of the sign. When necessary to assign the restrictive location of accessible parking stalls, signs are often placed atop sign posts which are protected by wheelstops; however, the overhang of vehicles is not a standard dimension resulting in many impacts with the sign posts. Concrete-filled steel bollards are the best alternative to this dilemma and other location where wheelstops are intended.

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