Safety Hardware and Materials for Safer, Forgiving Roadways

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ABSTRACT

Today's roadside design standards require removing fixed hazards, making them breakaway, or shielding them with a crash cushion or other barrier. This presentation will discuss the technology of breakaways as well as the history leading up to where we are today with this safety hardware.

Motorist safety is the number one reason for using breakaways on the forgiving roadway. The history of breakaways for signs and light posts has a 50 year history in the United States - from the slip base systems, the first implemented system - to omni-directional breakaways, meaning a system that breaks away with consistent, predictable behaviour, regardless of the vehicle's angle of impact.

The primary component of the system is a high-strength coupling, designed to break away quickly and cleanly upon impact, thus saving lives and reducing property damage. Breakaways have the structural capability of withstanding high wind loads on large signs and will still breakaway quickly and easily conforming to Road Safety Standards. Maintenance and cost replacement issues will be addressed and reasons for failure with past systems will also be discussed.

Transportation agencies placing greater emphasis on improving pedestrian safety and are finding MMA acrylic resin based road marking are a long-term, durable solution to color pavement markings and anti-skid surfacing. These markings not only offer increased safety to pedestrians, but also provide local authorities with a cost-efficient alternative to other road marking systems in the industry. The color stability of the area markings and the retained retro-reflectivity of accent stripes can be expected to reduce the number of pedestrian vs. vehicle accidents on major intersections. This presentation will show several applications in the US including Bike Lanes and Crosswalks.

1.0 BREAKAWAY SUPPORTS

Countries throughout the world are seeking ways to increase safety, increase compliance with traffic laws on roads and highways, and looking at best practices and strategies to reduce the number of fatal and serious injury crashes from posts and luminaire supports.

Motorist safety is the number one reason for using breakaways on the forgiving roadway. Today's design standards require removing fixed hazards, making it a breakaway, or shielding it with a crash cushion or other barrier.

Still approximately 34,000 fatalities occurred in the US and approximately 1.3 million fatalities occurred worldwide in 2010. 70% of one vehicle fatalities involve cars leaving the roadway and either overturning or colliding with fixed objects. Hazard removal or treatment using breakaway systems are preferred over the more expensive and still more hazardous installation of guardrails. Breakaways for ground mounted signs and luminaries can significantly decrease the severity of these accidents and resulting fatalities. (Figure 1.)

Figure 1

These incidents happen due to various factors:
- Driver error – excessive speed
- Falling asleep
- Reckless or inattentive driving
- Driving under the influence of alcohol, drugs, or medications
- Vehicle component failure (brakes or steering problems)
- Forced off road by another vehicle

Hazards they encounter:
- Unyielding sign and luminaire supports
- Non-traversable drainage structures
- Utility poles
- Trees
- Steep slopes
- Other unforgiving highway hazards such as blunt ends of guardrail and concrete barriers
- Breakaways can significantly decrease these fatalities.

At one time, Breakaways were not required in the United States. Today breakaway systems are required on a variety of posts. Light poles, traffic monitoring poles, weather station poles, call box poles, highway sign supports, residential poles, way finding signs, and any other roadside element requiring breakaway support.

1.1 HISTORY OF BREAKAWAYS

The history of breakaways for signs and light posts has 50 years of history in the United States - from the slip base systems, the first implemented system to the new omni-

directional breakaways; meaning a system that breaks away with consistent, predictable behavior, regardless of the vehicle's angle of impact.
Slip base breakaways were first introduced in the 1960's in the United States. Every US state currently has slip bases installed. Even those specifying omni-direction Break-Safe have old slip bases that have not been replaced.

In 1978, Break-Safe Omni-directional breakaway system was introduced and installed as the new State standard for ground mounted breakaway systems in Pennsylvania.

In 1985, 7 years after Pennsylvania became the first state to make Break-Safe the state standard, there were no recorded fatalities associated with Break-Safe. 25 years later, there are still none. Today, there are 37 states using this omni-directional system and 9 States who use it exclusively.

New Zealand, Australia, Canada and others have begun to use omni-directional breakaways and there is increasing global interest in this technology. Eastern Europe and the Netherlands are currently examining the use of breakaways for their roadways.

Until now, the use of energy absorbing posts in Europe has been the only form of yield supports used. However, as seen in many of the crash tests in the US, these energy absorbing posts, at high speeds, can entrap the vehicle causing 'yaw' which overturns the vehicle resulting in serious bodily harm.

1.2 EVALUATING BREAKAWAY SUPPORTS

The NCHRP350 report (National Cooperative Highway Research Program & Manual for Assessing Safety Hardware) and currently MASH 08, present procedures for conducting crash tests and in-service evaluation of roadside safety devices. (Safety devices including "Breakaways or Yield Supports (signs and luminaires)." In AASHTO's Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, Section 12 addresses the structural, breakaway and durability requirements for structures required to yield, fracture, or separate when struck by an errant vehicle.

1.2.1 Breakaways Need To Be Designed To Meet Both Structural And Dynamic Performance Requirements.

Dynamic requirements include:

a. The longitudinal component of occupant velocity at impact due to a vehicle striking a breakaway support, shall not exceed 5 m/s (16.4 ft/s)
b. Substantial remains of breakaway supports shall not project more than 100mm (4 inches.) The specified limit on the maximum stub height lessens the possibility of snagging the undercarriage of a vehicle.

Structural Performance requirements, Sign Post Spacing, and Pole size include:

a. Breakaway supports shall be designed to carry loads using the appropriate allowable stresses for the material used.
b. Wind Load Design up to 150 m/hr (240 km/hr) Basic Wind Speed
c. Multiple Post Spacing for signs: 7 ft (2.1m) between posts.

Breakaways are impact tested using the critical angle of impact:

a. Slip Base: 0-25 degrees
b. Frangible bases: 0-90 degrees
c. Frangible couplings: 0-90 degrees

1.2.2 Slip-Base or Omni-Directional coupling based system.

a. Slip Base

Sign slip bases work where the vehicle strikes the support in the direction of the traffic (notches). The upper post separates from the imbedded portion.

b. Omni-Directional Breakaways (and Frangible sign posts, primarily used on small sign posts)

These breakaways are designed to “break away” when a vehicle strikes at any angle of impact.

i. Frangible Bases – For small sign supports
- Tear Away
- Stripped Bolt
- Omni-Directional Breakaway (Frangible) Coupling

ii. Frangible Couplings – For large sign supports (The primary component of the systems are high-strength couplings.)

The Federal Highway Administration states on its product acceptance web page “the current criteria for breakaway supports focuses on the velocity change of the impacting vehicle and the height of the stub remaining after impact. Hardware that breaks away without slowing the velocity by more than 5 meters per second (about 15.4 feet per second) and leaves a stub with no substantial remains taller than 100 mm (4 inches) can be acceptable.” (Figure 2.)

FIGURE 2. NCHRP 350 – Crash Testing Requirement

The FHWA further states: omni-directional “breakaway supports that are placed near intersections or other locations where errant vehicles may come at them from all directions must be of an omni-directional design. Certain generic bases like the rectangular four bolt slip base or the inclined base are not designed to be omni-directional and will act like a non-breakaway support if struck from the side.”

2.0 SLIP BASE SYSTEM

Sign slip bases work where the vehicle strikes the support in the direction of the notches or traffic. (Figure 3)

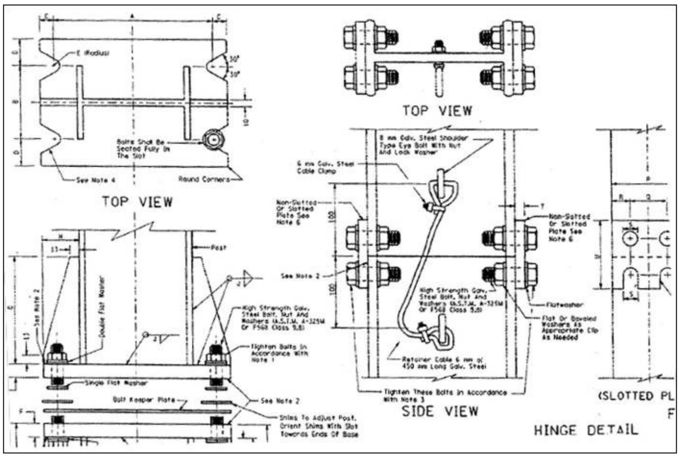

Figure 3.

- Slip bases are torque dependent to function properly as a breakaway device. The torque value is determined by the diameter of the bolt/nut. The smaller the diameter the less torque required.
- Slip bases should be field checked every year as they tend to “walk off” due to loosening that is caused by wind and road vibration. Slots in hinge plates can also cause slippage and can cause sign panels to blow over in windy conditions.
- Maintenance crews are often frustrated by downed posts (due to wind, etc) and they tend to “over tighten” the bases so their problem is solved. Of course this results in a non-breakaway post and a hazard to the motoring public.
- Slip bases are either omni-directional or uni-directional. Omni-directional slip bases are of the three bolt triangular design; but torque values must still be maintained. Four bolt slip bases (typical for multiple wide flange post installations) are uni-directional as they will only slip within a window of approximately 15 degrees from the centerline of the beam. And again the torque values must be maintained.

3.0 OMNI-DIRECTIONAL BREAKAWAYS

‘Omni-directional’ means that the support is symmetrical and will break safely when struck from any direction, or it has specifically designed to function properly at all angles. An added safety feature documented in the FHWA’s acceptance letter for Transpo Industries, Incorporated’s Break-Safe breakaway sign support system is the stub remaining after impact has a height of 0.3 inches (0.76mm).

Breakaways designed for very light vehicles pose difficulties because of the lighter mass momentum force at impact. The breakaways examined in this paper are precisely machined geometry.

The coupling design causes the system to fracture safely at relatively low force and energy levels. (Figure 4) A low stub height after impact allows for maximum safety even with variations in foundation height. The low stub height will not snag the under carriage of the vehicle where the gas tank is located.

The system is designed to breakaway quickly and cleanly upon impact, saving lives and reducing the cost of property damage**.** (Figure 5)

Figure 4.

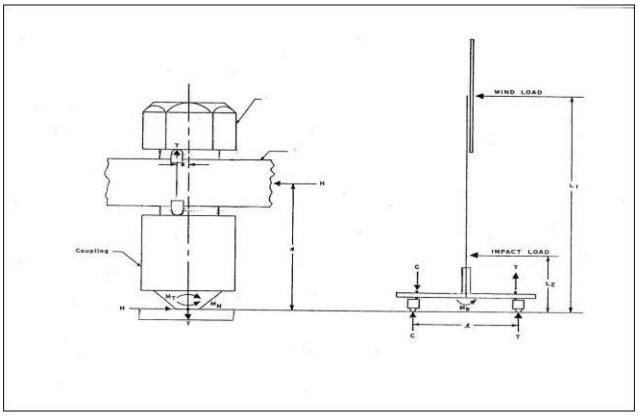

Figure 5.

Break-Safe (Figure 6) is an engineered system designed to accommodate different wind design speed and sign panel sizes. It is also designed to meet the new AASHTO 100 year winds. New National signing standards specify increased sizes for visibility and wind load levels. These changes create an increase in structural demands on sign supports. Break-Safe provides high structural load-carrying capacity.

Vehicle crash-tested in accordance with NCHRP Report 350 using 16m high(55ft), 450kg(1000lb) pole, Pole-Safe (Figure 7)provides high structural load-carrying capacity for luminaires. Extensive finite element analysis and simulated wind-load testing has been used to optimize the system for maximum loading conditions.

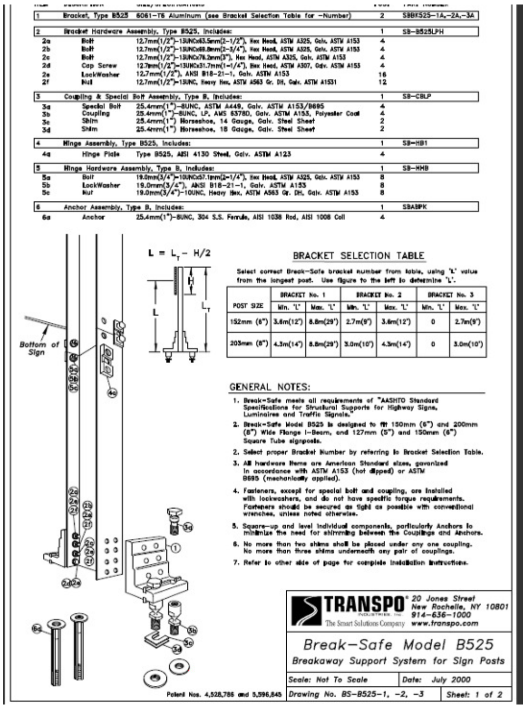

Figure 6. Break-Safe

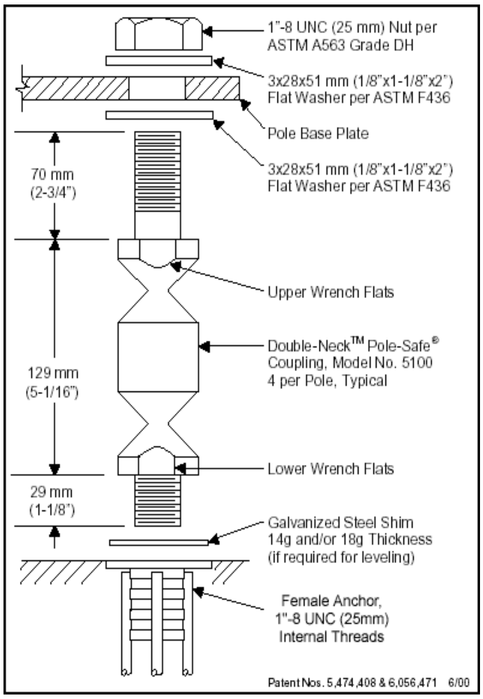

Figure 7. Pole-Safe

4.0 BREAKAWAYS CONCLUSION

Motorist safety is the number one reason for using breakaways. One of the key issues to ensuring greater safety in transport is to identify and treat hazardous locations and objects. By using Breakaway Supports that are designed to break away quickly and cleanly upon impact, with consistent, predictable behavior, regardless of the vehicle's angle of impact (omni-directional), will result in reduced property damage and lives saved.
Breakaways save lives. Omni-Directional Breakaways save more lives.

Omni-Directional Breakaway:

Downed Pole.

Couplings sheared and the light Pole was not damaged.

This sign was reinstalled the same day it was impacted. No damage to post or sign panel.

Slip Base Breakaway:

Often impacts without breaking away.

5.0 COLOR TREATMENTS FOR SPECIAL USE LANES AND PEDESTRIAN AREAS

Color Surfacing Materials are being used for traffic calming patterns and clearly defined preferential lanes. Increasing visibility for bike and bus lanes and pedestrian areas reduces unauthorized use and incursions, which, in turn, boosts safety especially in cities with high traffic flow. MMA acrylic resin based road marking are a long-term, durable solution to color pavement markings and anti-skid surfacing. The color stability of the area markings and the retained retro-reflectivity of accent stripes can be expected to reduce the number of pedestrian vs. vehicle accidents on major intersections.

5.1 COLOR PAVEMENT DEMARCATION FOR PEDESTRIAN AND VULNERABLE USERS

It has become apparent that other safety devices and systems for transportation infrastructure are needed to protect pedestrians as well as vehicular traffic. Cities throughout the world are seeking ways to increase compliance and safety on roads and highways while improving traffic flow. Bicycle lanes have been implemented to enhance bicycle access, bus lanes have been color marked to improve transit services and pedestrian plazas have been built to increase pedestrian safety and comfort. Such clearly delineated preferential lanes/areas have been proved to increase visibility and reduce unauthorized use, which in turn boosts safety, especially in cities with high traffic flow.

5.2 SPECIAL USE COLOR PAVEMENT DEMARCATION

5.2.1 Bike Lanes

As part of a world-wide effort to reduce greenhouse gasses, more and more people are using bicycles as a means to travel around urban areas. Cities have been working to develop and implement bicycle lanes adjacent to traditional vehicle lanes.

The increase in the number of city workers and students commuting on bicycles is illustrated in Figure 8.

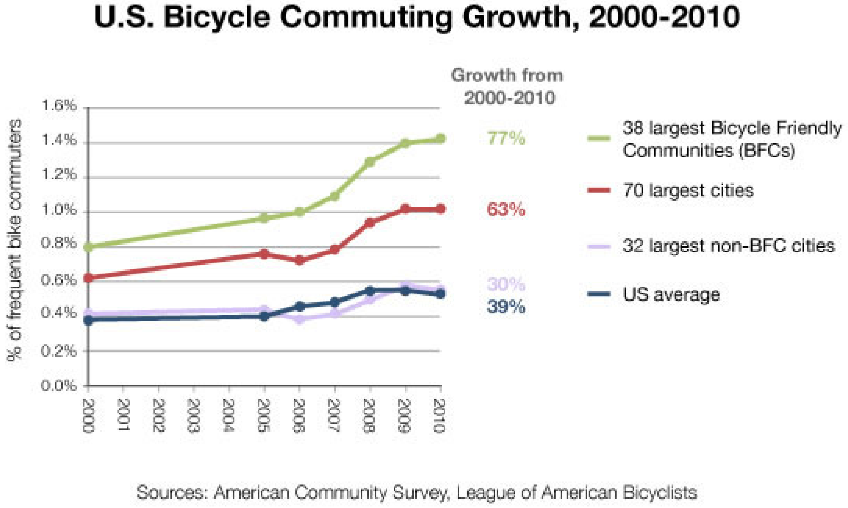

Figure 8.

Along with this increase in bicycle use the close proximity of bicycles and vehicles has caused engineers and planners to consider the safety of both types of users. Special colored pavement bicycle lanes have been installed and are being evaluated for their effectiveness with regard to safety. Some of the bicycle designated areas being tested are*(Figure 9).

Bike Lanes – Lanes with color pavement that enhance visibility and increase cycling lanes.
Buffered Bike Lanes – A diagonally striped lane between the bike and car lanes that provides no physical barrier from cars but offers some separation from traffic.
Bike Boxes – Advance stop lines for cyclists at key intersections about 10 to 15 feet ahead of the stop line for cars, increasing both visibility and safety.
Bicycle Boulevards – A modification of traffic-calmed streets specifically designed to facilitate cycling. Special pavement markings and signage are used to reinforce bicycle priority of such streets.

Figure 9. Bike Lanes with Color-Safe pavement markings

5.2.3 Bus Lanes

It has long been known that efficient public transportation is the single biggest contributing factor to acceptance and increased usage. In an effort to reduce vehicle congestion, pollution and increase efficiency of public transportation, some cities have begun to install dedicated bus lanes along major commuter routes.
Colored pavements in these special use lanes inform riders of bus route locations while alerting other motor vehicle operators of the special use lane and prohibiting stopping or parking in the bus lane. In cities around the world bus lane violations are being reduced with color pavement overlays.
New York City recently conducted a research project with new products for its bus lanes. (Figure 10)

Figure 10

5.2.4 Crosswalks

In the USA over 4,000 people are struck by motor vehicles each year and many cities have been dedicating their resources to reduce this figure. Color pavement is applied to crosswalks to increase safety in front of schools or areas with high accident rates in order to clearly inform drivers of a dangerous intersection.

Known for their high durability, increased wet-night visibility, skid resistance and optimal color stability, contrast area markings based on cold plastic (MMA, methacrylate resin) are increasingly being used to apply bright crosswalks to high traffic areas. The contrasting colors of these crosswalks alert drivers and have been proven to significantly reduce the numb er of pedestrians hit while crossing through traffic each year. An example of such an intersection is in Denver, Colo., at the intersection of Colorado Boulevard and Louisiana Avenue. (Figure 11) On average two people were struck each year by oncoming vehicles; one year five people were hit. Since red crosswalks were installed, only three people were struck in three years. Highlighting the brightness and safety aspects of these markings, various local news stations recognized the Colorado Department of Transportation (CDOT) for its dedication to improving the safety of all road users at Denver intersections.

With increased pedestrian safety proven, CDOT then had to find a durable product. Paint/epoxy did not have the bright color or durability needed. Thermoplastic was expensive. Color-Safe (MMA Resin based material) was chosen to use on three similar locations for its brightness and durability. It is easy to apply with no special equipment need.

Figure 11.

5.2.5 Pedestrian Plazas

In an effort to make cities friendlier to workers, residents and tourists some city streets are being converted into pedestrian-only plazas. Through the use of colored pavements, some incorporating unique artistic designs, pedestrians are assured that it is safe to move about without the fear of encountering a moving vehicle.

6.0 MATERIALS USED FOR COLOR PAVEMENT ON A ROADWAY SHOULD MEET REQUIREMENTS FOR COLOR RETENTION, SKID RESISTANCE AND DURABILITY.

Polymer based coatings can be formulated in a variety of colors and can incorporate glass beads for nighttime retro-reflectivity and increased safety. There is minimal disruption to traffic during application and the product has long term performance. The no trip, skid resistant surfaces are safety enhancements and pedestrian friendly.

They are simple to apply, require no special equipment, rapid curing, durable and result in areas with high visible and safe roadway delineation. Positive demarcation for bike and walking paths, crosswalks and toll lanes can be easily accomplished with a low unit installation costs.

Currently most pavement area marking materials are based on standard paint/epoxy technology and do not exhibit long-term resistance to color fading, cracking and abrasion. Thermoplastic materials are also being used, but they are expensive and require special equipment for application.

The next-generation area marking and anti-skid surface system is a polymer based resin with aggregate that is put down in one application. Its fast cure time allows the surface to be opened to traffic in as little as one hour. Applications are capable of obtaining full cure in a wide range of temperatures (40° to 100°F) without external heat sources. The material has excellent bonding strength to concrete and asphalt pavements allowing it to maintain its skid-resistant characteristics for many years of service.

2.3 COLOR PAVEMENT MARKING

Both the benefits of color treatments in modifying driver behavior and the increased public acceptance of color treatments is evident. The challenge facing municipalities is finding the appropriate material and the easiest implementation of that material without increasing maintenance costs.

CONCLUSION

Our society's commitment to safety reflects its compassion for individuals, even when those individuals do not behave responsibly. This societal commitment to safety does not eliminate the individual's responsibility for driving and behaving in a safe manner, but it does obligate all those involved in the building, operating, and maintaining of vehicles and roadways to make a concerted effort to protect the users of our roadways.

The use of breakaways and color pavement marking will help us get to our goal of reducing the worlds vehicular and pedestrian roadway fatalities.

RESOURCES

Recommended Procedures for the Safety Performance Evaluation of Highway Features, NCHRP 350 1993, Transportation Research Board, National Research Council.
AASHTO. 2009. Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, Fifth Edition.

*Latest Bike Lane designs and full descriptions are available in NACTO's Urban Bikeway Design Guide. www.NACTO.org

Author Biography

Arthur M. Dinitz is *Chairman and CEO of Transpo Industries, Inc.*

Mr. Dinitz has been actively engaged in the introduction and development of new roadway safety products, specialized materials and other products utilizing new technology in the transportation construction field since founding Transpo Industries in 1968.

He is the Co-chair of AASHTO/AGC/ARTBA Joint Comm. on New Technologies and Materials and was a member of NAS Research and Technology Coordinating Council for FHWA, Vice Chair of Exec. Board for Highway Innovative Technology Center of ASCE, President of Industry Committee of ITE and ARTBA, member of TRB and ACI, and Former Vice Chairman, International Road Foundation (IRF) – Washington. He is ARTBA's National Highway Safety Award recipient (2001-2002), TRB's National Roadside Safety Award (2006), Honored as one of the "Top 100 Private Sector Transportation Design & Construction Professional of the 20th Century" by ARTBA,

Mr. Dinitz has a Bachelor of Mechanical Engineering from New York University.