IMPROVING THE CRASH COMPATIBILITY OF CARS AND ROADSIDE POLES

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ABSTRACT

Car to pole impacts account for a large proportion of car occupant casualties in many motorized countries. Each year in Australia about 2000 vehicles crash into timber power poles resulting in approximately 100 fatalities and 1000 serious injuries at a community cost of about A$500 million. The estimates for North America are over 1000 fatalities and over 100,000 serious injuries each year, with an estimated 10-fold increase in costs. Historically the primary countermeasure used by road safety authorities has been to move utility/power poles away from the roadside. While this may reduce the risk of an impact, moving the position of the timber pole has little effect on the outcome if an impact occurs. To reduce the risk of injury there is a need to change the properties of the pole, so that the pole acts to stop the car while retaining integrity ensuring that neither becomes an unrestrained hazard.

This paper presents the results of a program aimed at developing a utility pole that absorbs energy and yields sufficiently to stop the vehicle in several metres at survivable decelerations with no intrusion into the occupant space. This has been achieved by using composite materials supplemented with built in energy management systems. To test the impact properties of the prototype, we conducted ten full-scale frontal crash tests using a variety of car sizes at impact speeds of 50, 80 and 100 km/hr. The performance of the poles during the tests was monitored using multiple high-speed cameras, and accelerometers were fitted to the vehicles on later tests.

The results demonstrate the superior impact performance of the composite poles and the ability of these poles to safely stop impacting vehicles even at high impact speeds, while retaining enough integrity to ensure cables carried by the poles remain intact and supported above the ground.

This superior impact performance carries substantial potential safety benefits. Furthermore, the projected whole of life costs of the composite pole are less than existing timber poles. The lighter weight and lower cost of the poles also assists the primary countermeasure of relocation away from the road. Limitations of the preliminary test program are the lack of instrumented test dummies that means that these results cannot be communicated directly in terms of injury criteria. However the reduced decelerations measured in the vehicle, and the retention of the occupant compartment even in the highest test speeds strongly indicates likely reduction in injury risk.

The composite pole used in these tests start as a standard production utility pole already in limited use in North America. It is then enhanced to absorb energy in a controlled manner, prevent unrestrained hazards and can keep the power/communication cables supported. Widespread use of these composite poles could prevent considerable serious injury, death and associated community cost.

INTRODUCTION

In one Australian state alone, between 2004 and 2008 there were 171 fatalities and 5,060 injuries following collisions with utility poles with an estimated annual cost of $178 million per year (RTA, 2009). Across Australia, these numbers would be expected to reach 100 fatalities per year, and many more serious injuries. Casualties resulting from collisions with utility poles are mainly an urban problem, and account for a large proportion of the fatality problem in at least Australia, North America and the ECU (RTA, 2009; TRB, 2004; Thomson et al, 2006).

The hazard created by robust timber utility poles arises from their usual close location to the roadway. To reduce this hazard the primary response has been to try to reduce the number of poles and ensure that those that remain are situated outside a designated safety zone i.e. set back a certain distance from the roadway. However, this measure does not address the severity of an impact should one still occur. Moreover, poles are used to provide necessary roadside utilities such as lighting, and moving all poles a safe distance from the road side is not always possible.

Historically most roadside poles have been constructed from wood. Attempts to design safer poles have focused on using breakaway features and safety guards (Foedinger et al, 2003;TRB, 2004). Breakaway poles are designed to yield upon impact, and while this feature potentially reduces the severity of the initial pole impact, the broken away pole becomes a hazard as a secondary impact to the vehicle, or in impacts to other vehicles or road users. It also disrupts the utility being supplied by the pole. A better, more efficient approach would be to design a pole that absorbs energy to reduce the severity of the impact, but remains in place- so as to reduce any further hazard and a reduced possibility of disruption to services.

Modern composite technology presents the possibility of designing a new generation of energy-absorbing poles. This potential has been studied by Elmarakabi et al (2006, 2009) using finite element analysis who demonstrated the theoretical benefits to vehicle deformation and deceleration that might be achieved with this technology. Foedinger et al (2004) went further to develop a prototype energy-absorbing fibreglass-reinforced filiament wound tapered utility pole and demonstrated the ability of this device to mitigate crash severity in two frontal impacts at 50 and 70Km/h.

In our research program, we aimed to modify a standard production composite pole so that it would absorb energy and bring vehicles to a stop over a few metres in a controlled manner from speeds in the range of 50 to 100 km/hr, without the pole breaking away from its base in the ground. Standard production composite poles manufactured using protruded techniques are already in limited service in North America. Our aim was to add crash severity mitigating features to these poles that already provide an advantage in reduced weight, an improved strength-to-weight ratio, ease of installation, low maintenance, and environmental friendliness over wooden poles.

This paper reviews the development of the prototype design to achieve this, and results from preliminary testing demonstrating the ability of the safe system pole to reduce injury potential while maintaining integrity of the utilities being provided.

THE SAFE SYSTEMS POLE

The production pole that forms the foundation of the Safe Systems Pole was originally sighted in its use as a waterways channel marker. The information that the pole's structural characteristics could be relatively easily altered by changes in the mixes of binding resin and cloth led to the concept that such a pole could be developed to progressively yield and stop cars in a controlled manner.

TEST PROGRAM

The U.S. Department of Transportation's recommended procedures in the safety performance evaluation of highway features (NCHRP350) formed the basis of the test procedure.

All tests were conducted at the New South Wales RTA's Crashlab, external test facility suitable for the testing of roadside furniture located in Sydney, Australia. .

Initial tests assessed the base energy absorption properties of the composite poles with a variety of treatments of the standard base. Once a preliminary understanding was gained of how the fronts of vehicles relate with the base of the poles, a further round of tests reviewed the effect of various prototype enhancements to the poles to improve the control of the energy management systems in the pole.

All testing was conducted using two popular typical models of passenger cars at speeds of 50, 80 and 100 km/hrThe Hyundai Excel was used as a representative 'small car' and the 'large car' chosen was a Ford Falcon sedan.

Dimensional specifications for the Hyundai Excel were:-

- kerb weight of 967 kg
- overall length of 4.103 metres
- wheel base of 2.4 metres

Dimensional specifications for the Ford Falcon sedan were:-

- kerb weight of 1541 kg
- overall length of 4.906 metres
- wheel base of 2.791 metres

All tests were recorded using three high speed cameras, and one real time camera.

Some of the later tests included accelerometers fitted in the region of the "B" pillars of the vehicles.

Assessments of the rate of deceleration of the vehicle in the earlier tests were simple measurements of average deceleration based on the length that it took the vehicle to come to a stop.

Ten full-scale crash tests were conducted using popular typical models of passenger cars at speeds of 50, 80 and 100 km/hr.

Table 1
Pole Test Program

Test Number	Speed	Outcome
Assessment of minor modifications to basic pole		
Test 1 B09044	80 km/hr	
Test 2 B09045	80 km/hr	
Test 3 B09046	80 km/hr	
Test 4 B09048	80 km/hr	Vehicle brought to a stop in a distance of approximately 5 metres
Mark I Modified Poles		
Test 5 B10001	50 km/hr	Vehicle brought to a stop in a distance of approximately 1 metre
Test 6 B10002	80 km/hr	Vehicle brought to a stop in a distance of approximately 3 metres
Test 7 B10003	100 km/hr	Vehicle brought to a stop in a distance of approximately 4 metres
Mark II Modified Poles		
Test 8 B10014	100 km/hr	
Test 9 B10028	80 km/hr	Vehicle brought to a stop in a distance of approximately 3 metres
Test 10 B10029	100 km/hr	

RESULTS

The results of the individual tests can not be described in any detail for commercially in confidence/ intellectual property reasons

What can be said, and what can be shown here, is that the test program demonstrated proof of concept to the extent that:-

- at the NCHRP350 50 km/hr test, the pole deformed approximately a metre which with vehicle crush yielded an overall likely occupant average deceleration rate of 10g

- at the NCHRP350 80 km/hr test, the pole brought the vehicle to a stop in approximately 3 metres with an average deceleration rate in the order of 8 - 9g. There was no intrusion into any of the occupant compartments and the doors could be opened without extra force or the use of tools

- at the NCHRP350 100 km/hr test with a heavier vehicle, the vehicle was brought to a stop in approximately 5 metres. It had an average deceleration rate of 8g. The doors could be opened after the test without the use of additional force or tools.

Figure 2. Car about to impact pole at 80 km/hr

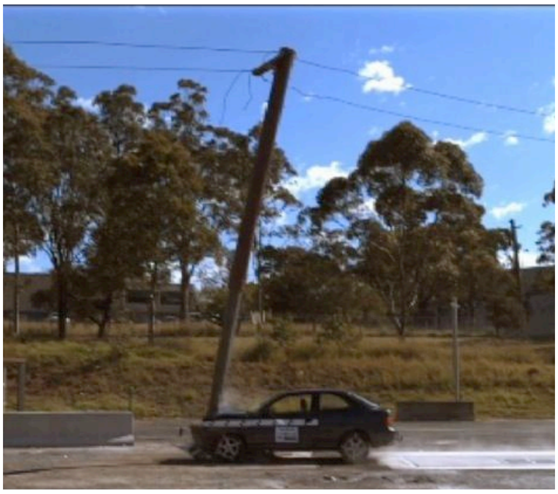

Figure 3. Pole yielding and car slowing

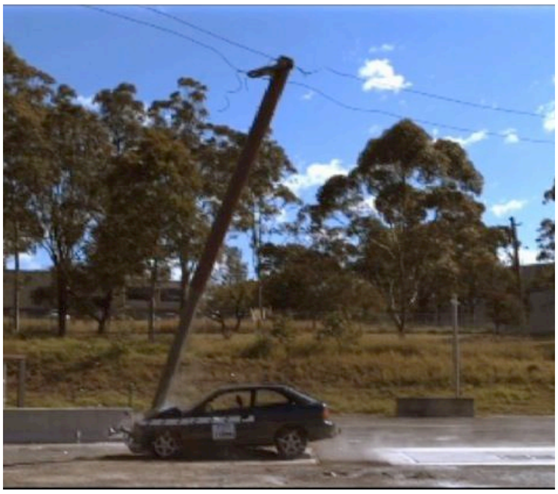

Figure 4. Pole continues to yield

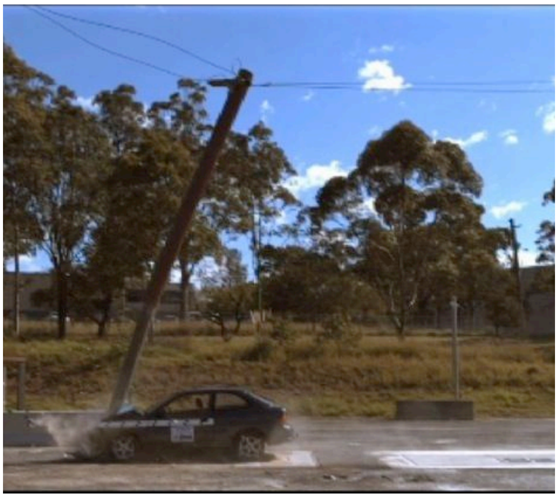

Figure 5. Car nearly stopped

Figure 6. Some minor rebound

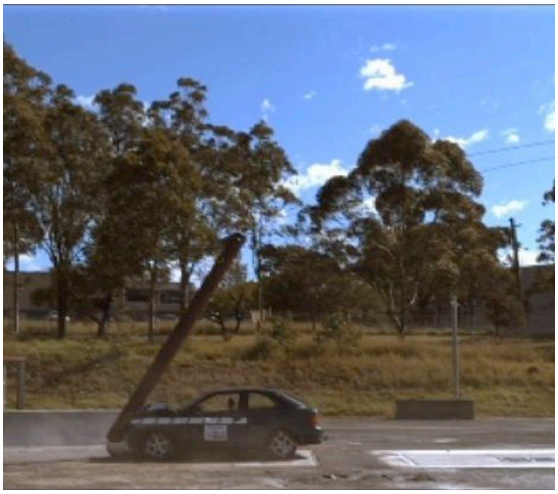

Figure 7. Car stopped, pole supporting cables above roadway

THE FUTURE

This concept has been demonstrated to meet our aims of developing a safe pole system that can mitigate crash severity while retaining integrity of services. The pole's energy management systems have been tuned to result in relatively gentle controlled deceleration for the vehicles in frontal impacts. Simultaneously during the program, systems for minimising the damage to the cables carrying power and communication have also been trialled.

The average deceleration for a stop from 80 km/hr over a distance of 3 metres was approximately 8.4g. As is well established from real world crashes and laboratory crash testing, occupant compartment accelerations in this range result do not cause injury to restrained vehicle occupants. At the same time, the energy managed stop can result in significantly reduced direct loads on the cables etc, so that the likelihood of damage to the power and communications systems (or utilities being carried by the pole) is reduced, or entirely prevented.

There is a need for a further test program before attempting to proceed to real world production (commercialization) of the product.

This next test program will have the aims of:-

- extending crash test scenarios to side on impacts,
- Further fine-tune energy management and pole retention systems
- Further fine-tune systems for minimising potential damage to the cables carrying power and communication

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