Edge Restraints for Segmental Conrete Block Pavements

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SUMMARY

A serious cause of distress in block paving can be loss of integrity due to inadequate edge restraint. Thermal, moisture or traffic induced loads can cause lateral displacement of edge restraints and pavers. Failure then progresses in from the distressed edge as the pavers open up and lose any interlock which existed. The methods used to prevent movement include restraints of concrete (reinforced and unreinforced), pavers, masonry, stone, timber and special patented products. When deciding what type of edge restraint to use, structural capacity and cost must both be taken into account. The investigation reported in this paper involved the evaluation of the effectiveness of a patented extruded PVC product as an edge restraint. Testing was carried out on a small section (1800 mm x 1400 mm) of laboratory constructed pavement which consisted of 150 mm of sand, 100 mm of crushed rock, bedding sand and pavers. Loads were applied 250 mm in from, and at the restrained edge of the mini-pavement until failure occurred. It was found that the patented extruded PVC provided adequate lateral support, similar to a 100 mm x 150 mm deep, unreinforced concrete edge beam. The load applied exceeded those which would normally be encountered in normal residential situations. The increased ease of installation provided by the patented PVC product must be balanced by the increased material cost.

INTRODUCTION

The aim of the project reported here was to study the capability of a patented polymer edge restraint to resist lateral loads transfered to the edge of a pavement and to prevent paver joints opening and subsequent loss of pavement serviceability.

The design of segmental concrete block paving depends on a large range of principles which have been described in great detail elsewhere (1), (2). The principle which is unique to block paving and which forms the keystone of all design is that pavers are able to develop interlock between all adjacent pavers. This interaction allows effective distribution of loads through the paver surfacing into the main structural layers of road base and sub-base. Interaction however depends on the effective transfer of stresses via sand filled joints and it could be said that the overall performance of the pavement structure depends on the effectiveness of the joints.

If joints are washed out or widen then the stress transfer mechanisms are degraded and the pavement no longer behaves as "a coherent, interacting structure" (2). Design of block surfaced pavements are dependent upon the use of some equivalent moduli for use in mechanistic design and moduli values quoted vary from around 1000 MPa up to above 7000 MPa. Assuming that the actual number adopted represents the true behaviour then any loss of stress transfer will result in a reduced effective moduli and an accompanying loss in pavement life.

EDGE RESTRAINTS

Edge restraints may be defined as a device "intended to prevent different pavement layers moving sideways as a result of expansion due to thermal or moisture, or traffic induced stresses", (3). In this paper the phrase is used to describe a system used to prevent pavers moving under the effect of lateral stresses generated by traffic wheel loads.

Numerous materials may be used for edge restraints for public and private roads and driveways. In the case of public roads in urban areas the restraints typically are kerbs of concrete, stone sets and special pavers or building foundations. In rural areas and private driveways narrow edge beams or special preformed devices are more commonly used.

Pave-Edge

Pave-edge is an extruded polymer (UV resistant PVC) section shown diagrammatically in Figure 1. The section shown costs about AUS $4.00/m retail. The paver sits above the cantilevered bottom section and against the vertical riser. The edging is "nailed" to the base/sub-base via variable length, 10 mm (3/8") steel posts which pass through pre-drilled holes in the edge section, into the pavement. The bedding sand is then applied over the road (and cantilevered base of the pave edge) as normal. The benefits claimed by the manufacturers of pave-edge include the following.

- the only self supporting edge restraint designed exclusively for pavers
- made from strong environmentally safe PVC compound
- available in rigid and flexible, straight and curved sections
- invisible when installed
- will not rust, warp or otherwise deteriorate
- lightweight, easy to install and permanent
- proven worldwide in a wide range of applications

Wheel loads are transfered by a number of possible mechanisms. Vertical loads on a paver sitting on the cantilevered section transfer directly into the pavement. Lateral components from the load are transfered via the vertical riser, down the lateral support member, into the pavement. Lateral movement of the section is prevented by the friction developed between the section and the pavement and also by the steel posts which go through the entire section as shown in Figure 1. The number of steel posts used can be selected to balance the design loads. The pave-edge is continuous and all edge pavers sit on the cantilevered section. There is thus some small increase in load spreading capability due to the continuous section under the pavers along the edge of the pavement.

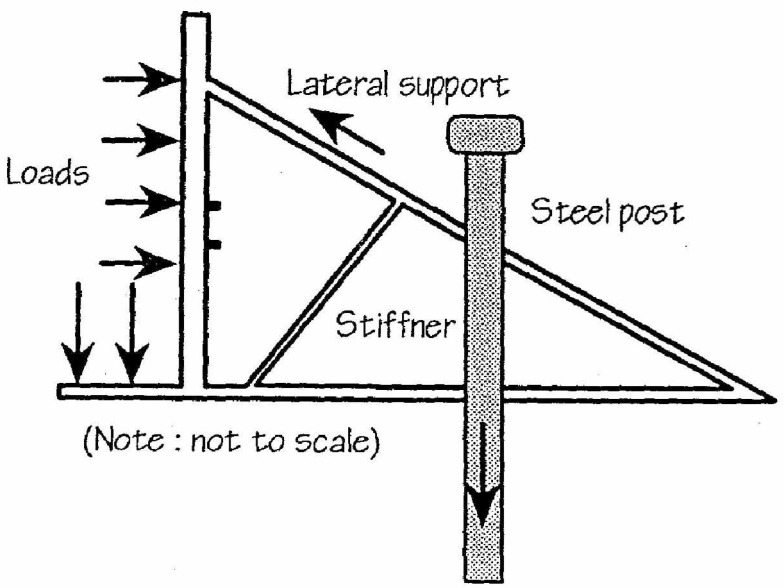

Figure 1. Schematic representation of pave-edge

JOINTS

The effectiveness of block paving depends upon load transfer between pavers which in turn depends on joint spacing and particle size distribution of the joint filler sand. A space in the order of 2-4 mm must exist to fill with sand to prevent paver to paver contact and associated spalling. If joint spacing becomes larger in comparison with the maximum particle size of the jointing sand then loss of interlock will occur. Also if the maximum particle size of the sand is greater than around 0.5 of the joint space, difficulty occurs with filling the joint. If the filled joint widens, say due to edge restraint displacement, then the effective depth of filler sand is reduced and its thickness increased. Both of these contribute to a loss of interlock and lead to pavement degradation.

TESTING PROGRAM

A series of model pavement structures were tested under static loading, simulating a single tyre as shown in Table 1. The model pavements were tested at their edges and approximately 250 mm from the edge to represent the worse types of loading. The edge support conditions were the edge-pave section and a concrete edge beam of approximately 100 mm wide and 150 mm deep, cast in situ. The concrete edge beam was allowed to cure for at least 7 days prior to testing and the mix designed to ensure that the 7 day strength was equivalent to that attained in a normal mix at 28 days.

Table 1. Model pavement test conditions

Pavement type/test	Edge material	Tests
Strong profile #1	Pave edge	1 edge, 1 internal
Strong profile #2	Pave edge	1 edge, 1 internal
Strong profile #3	Pave edge	1 edge, 1 internal
Strong profile #4	Concrete beam	2 edge, 1 internal
Weaker profile #5	Pave edge, concrete	4 edge

Pavement

The pavement was constructed in a customised, reinforced container of 1800 mm x 1400 mm x 350 mm. Two different pavement profiles were used and the first is shown in Figure 2. In the first structure, 150 mm of loosely compacted sand was used as the sub-base material and 100 mm of crushed rock used for the base material. Pavers (60 mm) were placed on 30 mm of bedding sand, joint sand applied, and a flat plate vibrating compactor used to bed-in the pavement. In the second profile an attempt was made to produce a weaker structure and the bedding sand and pavers were placed directly on 250 mm of loosely compacted sand base and sub-base. In both cases the base and sub-base were constructed over the full area of the container while the pavers and edge restraints were laid over the central 930 mm of the surface parallel to the 1800 mm side of the container.

The base preparation specified by the manufacturers of pave-edge is a well graded, minus 19 mm (3/4") crushed limestone or equivalent, compacted to at least 95% modified Proctor density. Recommended base depths vary with application and subgrade conditions but a general guide is 100 mm to 150 mm for pedestrian use, 150 mm to 250 mm for light vehicular and 450 mm to 900 mm for commercial or heavy traffic. The pavements tested in this project would fall in the light vehicular category.

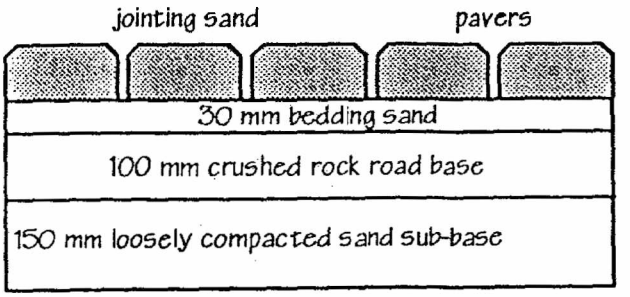

Figure 2. Pavement profile tested

Loading

Loading was applied via a pneumatic jack and a 250 mm diameter loading platen to approximate the contact area of a standard tyre on a single wheel, single axle configuration. Deflections were made at set load increments over a grid surrounding the load platen to obtain a deflection bowl (Figure 3). Loading was applied until the maximum pavement deflection exceeded 15 mm or until the load bearing capacity of the pavement had been significantly reduced (also refer to Figure 4).

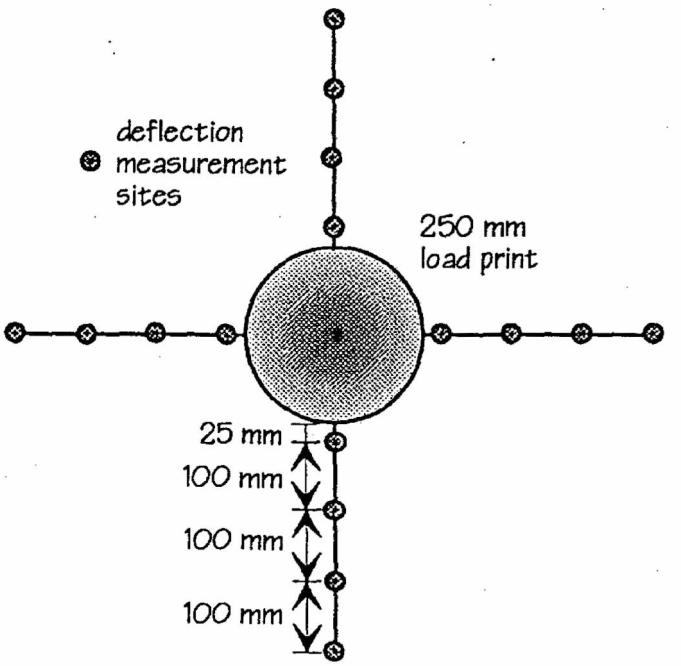

Figure 3. Plan of load/deflection test set-up

TEST RESULTS

Deflection bowl information was obtained for all the testing carried out and the data accumulated is much too great to be fully presented here. Some summarised data is provided in Table 2 which lists central, maximum bowl deflections at the load platen, at applied loads of 30 kN and 60 kN. An "inner" load refers to a test where the load platen outer edge was located 250 mm from the edge restraints and an "edge" load indicates loading at the very edge of the pavement. It should also be noted here that the standard load in Australia for an "equivalent axle" for single wheel, single axle configuration is 30 kN/wheel. All the test data presented in Table 2 has been corrected for initial bedding in of the load platen. The typical load/deflection plots obtained are seen in Figure 5 which shows the data for pavements 4 and 5, loaded near the concrete edge beam.

In Figure 5 the uncorrected deflection profile for the pave-edge restrained pavement for loads of 10 kN, 20 kN, 40 kN and 60 kN is shown. Loading was at the edge of the pavement, adjacent to the pave-edge material and the profile is for deflections 125 mm in from and parallel to the edge (also refer to Figure 3).

Figure 6 compares the uncorrected deflection profiles for the pave-edge and concrete edge beam tests for pavement 5, again loaded adjacent to the edge restraint. The data is for load levels of 10 kN and 20 kN for each of the two restraints.

A comparison is made in Figure 7 of lateral deflections for the concrete edge beam and pave-edge in pavement test 5 (also refer to Figure 4). Deflections were taken at the side of the restraint, adjacent to the outer edge of the load platen centre. The plot shows incremental deflections for the full range of loading up to 80 kN.

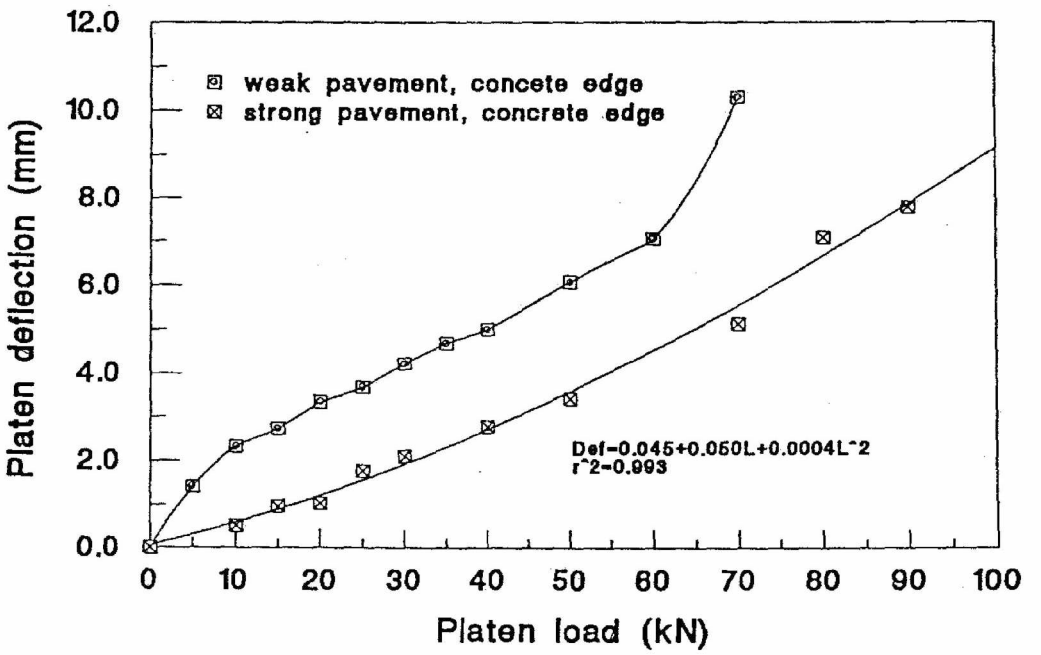

Figure 4. Typical load deflection plot

Table 2. Deflections at load platen

Test Pavement	30 kN load		60 kN load	
	edge	inner	edge	inner
1 (PE)[1]	ID[3]	1.8 (0.9)	ID	4.1
2 (PE)	1.6 (0.8)	1.5 (1.0)	4.4	4.0
3 (PE)	0.9 (0.8)	1.3 (1.5)	2.6	2.8
4 (Conc)[2]	1.8 (0.1)	1.9 (0.1)	4.4	3.7
5 (Conc)	2.0 (0.0)	NA	4.0	NA
5 (PE)	2.1 (0.3)	NA	4.5	NA
5 (Conc)	2.6 (1.5)	NA	5.6	NA
5 (PE)	2.0 (0.6)	NA	3.9	NA

Note
1 "PE" indicates a test using pave-edge
2 "Conc" indicates a test using concrete edge beam
3 "ID" indicates insufficient data
4 Numbers in brackets are the estimated deflections before "elastic" behaviour.

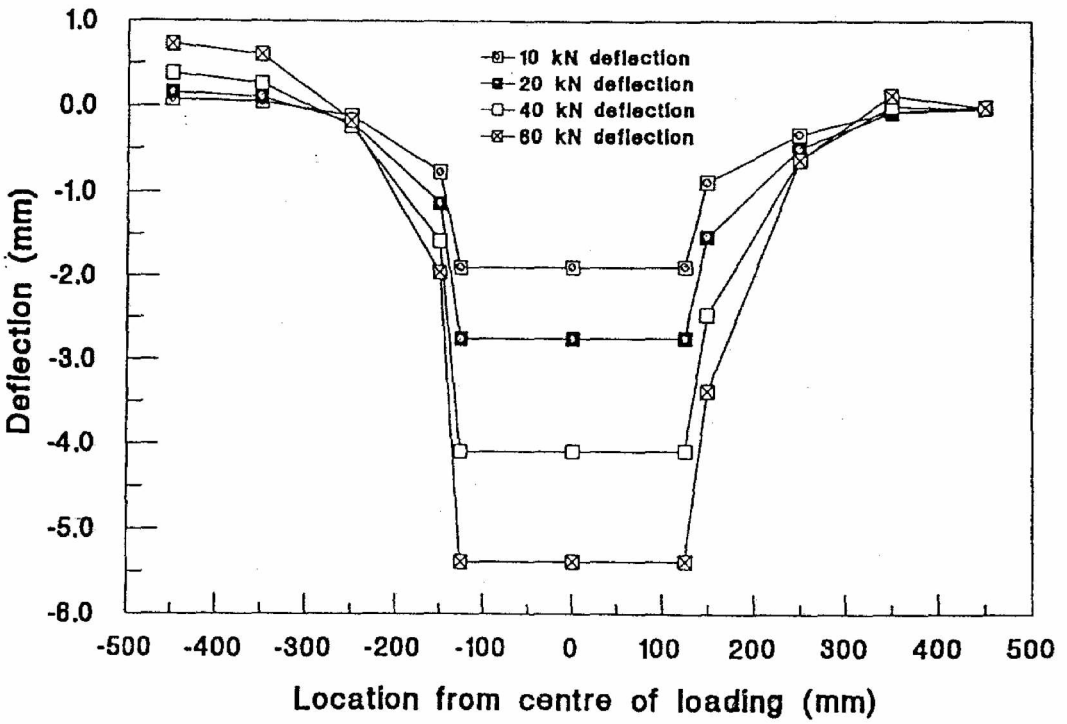

Figure 5. Deflection profiles for weak pavement, pave edge

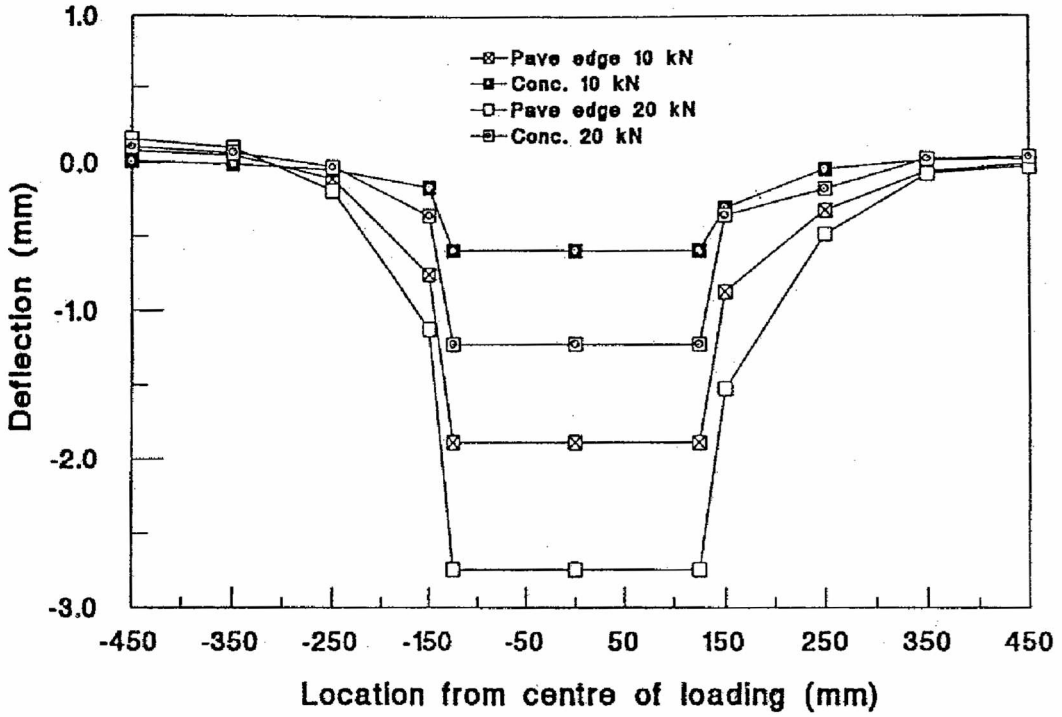

Figure 6. Comparison of deflection profile for concrete and pave edge

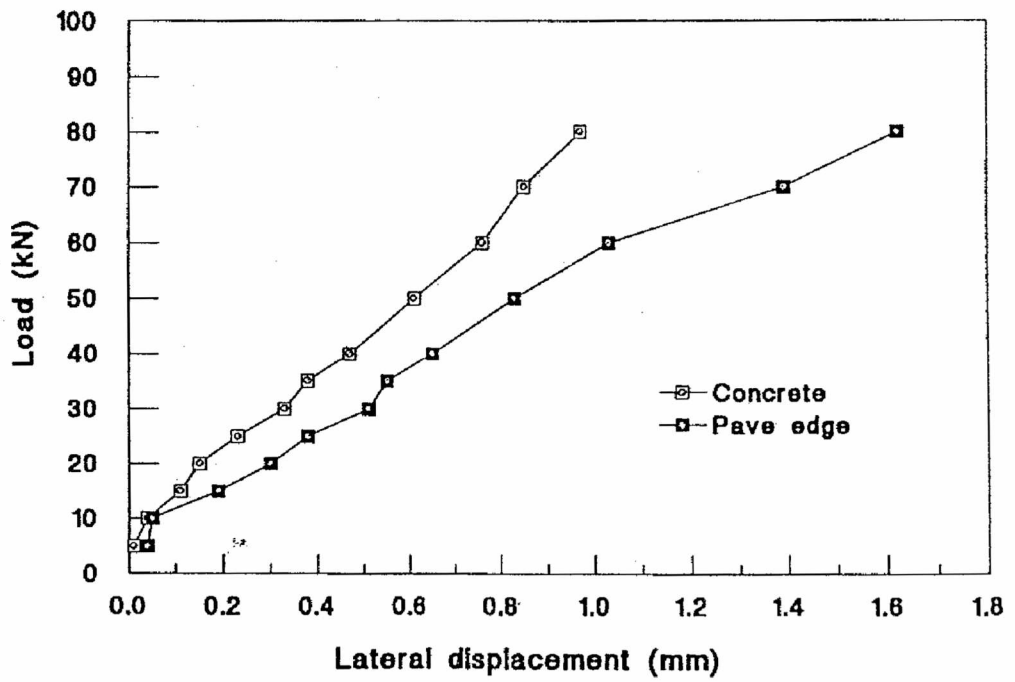

Figure 7. Comparison of lateral deflection of concrete and pave edge

DISCUSSION

There was a variation across the test pavements in the amount of deflection necessary before the pavement responded "elastically" to the applied loads. The deflections required varied between zero and 1.5 mm, although generally the amount required was around 0.8 mm. The variability reflected the amount of effort used in laying and bedding in the pavers. This phenomena could be compared to the amount of movement which takes place in full scale pavements before lock-up of pavers occurs.

As expected there was a slight difference between the capacity of the two pavement types. The stronger pavements had an average deflection at 30 kN of 1.54 mm (standard deviation 0.35 mm) compared to the average deflection of 2.18 mm for the weaker pavement (standard deviation of 0.29). The average deflections at 60 kN were 3.80 mm and 4.50 mm respectively for the strong and weak pavements.

After consideration of all data it was concluded that there was no discernible difference in performance between the performance of the concrete edge beam and the pave-edge restraint. In the weaker pavement (Table 2) the concrete edge beam pavement had an average maximum deflection of 2.35 mm at 30 kN while the pave-edge pavement had an average maximum deflection of 2.05 at the same load.

The testing carried out in the study was for a single load cycle. It was observed that the unreinforced concrete edge beam cracked during testing but maintained its integrity. During repeated loads however, these cracks could be expected to open over a large number of cycles and reinforcement would be necessary to maintain the edge restraint. The use of reinforcement in this project would not have changed the data obtained.

The costs of materials, installation and maintenance will greatly influence the final decision of what edge restraint system to use. Since costs vary greatly from country to country no attempt is made to analyse the different installation costs. It may be said however, that the material costs for edge-pave will generally be higher than for the more labour intensive methods such as cast in place concrete. On the over hand, installation costs for the edge-pave material will likely be less than for the more labour intensive methods.

CONCLUSION

The edge-pave product was approximately equal in structural performance to an unreinforced 100 x 150 mm concrete edge beam in resisting vertical loads. Both products were able to resist lateral movement at wheel loads in excess of 50 kN.

The selection of the method used to restrain the pavement will greatly depend on cost differentials based on material charges, labour rates and maintenance costs. Thus different restraint systems will be used in different countries (and applications) as the relative level of those costs change.

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