COLLISION TESTS WITH BREAKAWAY STREET LIGHTING COLUMNS FITTED WITH A SUSPENSION CABLE

by


and

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COLLISION TESTS WITH BREAKAWAY STREET LIGHTING COLUMNS FITTED WITH A SUSPENSION CABLE

ABSTRACT

Low speed and high speed collision tests have been carried out to investigate the feasibility and effectiveness of connecting the tops of breakaway columns by a steel suspension cable so that after a collision the shaft of the column involved is left suspended between the two adjacent columns, and does not fall onto the carriageway or footpath.

The tests showed that a suspension cable can be easily attached to the tops of breakaway columns, and the restraint put on the columns does not significantly increase the damage to the car or the risk of serious injury to occupants.

Due to the large final deflection of the suspension cable there is a risk of the lower end of the column obstructing the opposite carriageway after a collision if this type of installation without barriers is used on a 4 m central reserve of a dual carriageway road. It also appears that after an impact adjacent columns would need to be examined and the flange bolts changed.

1. INTRODUCTION

Previous collision tests (1) (2) (3) have shown that the deceleration of a private car and the injuries to occupants resulting from a collision with a conventional street lighting column can be considerably reduced by fitting a breakaway joint in the shaft of the column near ground level. In collisions at speeds greater than about 50 km/h the bottom of the shaft is thrown upwards and forwards so that the colliding car travels underneath it and is virtually undamaged. If the columns are mounted at least 1.5 m from the carriageway on the verge of an ordinary road or behind the hard shoulder of a motorway the final position of the shaft is off the carriageway and no danger is likely to arise to following traffic. When columns are mounted on or near footpaths there could be a danger from the columns falling on pedestrians which might add to the risks to them from the vehicle itself. If breakaway columns are to be installed on a central reserve of normal dimensions or on a footpath it has been suggested that means be adopted of restraining the shaft after a collision to prevent it falling onto the carriageway or footpath.

Low speed and high speed collision tests have therefore been carried out to assess the feasibility and effectiveness of connecting the tops of breakaway columns with a steel cable so
that after a collision the shaft of the column involved is left suspended on the cable between the
two adjacent columns. The latter have been done particularly with reference to the dual carriageway
situation.

2. CABLE REQUIREMENTS

The problem of estimating the size of the suspension cable required was considered from two
aspects. Firstly the probable loads induced in the cable during and after the collision were
estimated, and secondly the load due to the tightening of the cable to produce a given sag in the
static condition was calculated. Allowance has not been made for possible loads induced by wind
pressure on the cable or effects of ambient temperature changes, as it is thought these are probably
within the order of accuracy of the loads after collision.

From examination of high speed cine records of previous high speed collision tests on break-
away columns it appeared that very little horizontal movement took place at the top of the column
in the early stages of an impact. The main motion was a rotation of the shaft in a vertical plane
about a point near the top of the column causing the base of the shaft to rise and allow the colliding
car to travel under the column. In all cases the column finally fell in a roughly horizontal attitude
the top of the column striking the ground near the root section. It was therefore assumed that with
a breakaway column attached to a suspension cable the principal load in the cable would occur
as a result of the weight or part of the weight of the column being imposed on the cable in the later
stages of the collision. Using this assumption the tension in the cable due to the weight of the
column was calculated to be about 40,000 N. A 9 mm diameter 6 x 19 group road stand wire rope
with fibre core to the appropriate British Standard (4) was therefore selected. This rope had a
nominal breaking load of 51,750 N with a mass of 0.34 kg per metre.

A simplified calculation of the tension in this rope in the static condition showed this to be
considerably lower than the tension arising from the dynamic load during the impact; for a sag of
about 0.3 m over a span of 36 m the figure was approximately 1500 N.

3. LOW SPEED TESTS

3.1 Object of tests

The low speed tests were designed to investigate alternative methods of attaching the suspen-
sion cable to the column so that it would effectively restrain the column but be simple to fit.

3.2 Method of test

In these tests a tubular steel column 10 m mounting height incorporating a breakaway joint of
the type developed at the Road Research Laboratory from a design suggested by the Cambridge
University Engineering Department was installed as the centre of a group of three columns at a
spacing of 36 m. The outer columns which were of the non-breakaway type were provided with guy
ropes, the suspension cable being stretched between the tops of the three columns and anchored
to the ground at each end.
The centre (test) column was erected at the bottom of a sloping ramp, which was used to accelerate the test car of mass 815 kg to a collision speed of about 25 km/h. Plate 1 shows the installation before Test No. 3.

Strain gauges were fitted in the spans of the suspension cable at either side of the test column, the output from these being recorded on a galvanometer recorder. Accelerometers fitted in the test car and connected by trailing cables to a multi-channel oscillograph recorded the deceleration of the car during the collision. The recording instruments were housed in the caravan shown in Plate 1.

3.3 Tests carried out and results

3.3.1 Test No. 1 In this unsuccessful test the suspension cable was attached to a fitting half way along the bracket arm. During the collision the column twisted and the fitting on the bracket arm broke away allowing the column to fall freely.

3.3.2 Test No. 2 In this unsuccessful test the suspension cable was attached to the top of the test column by a swivelling bracket. During the collision the suspension cable became detached at the first column of the installation when the tension in the cable had reached 16,000 N, allowing the test column to fall.

3.3.3 Test No. 3 In this successful test the column was attached to the suspension cable by a short length of similar cable clamped to the main cable by 'bulldog grips', and fixed to a fitting on the column just below the bracket arm. The final version of this fitting as used in the later high speed test is shown in Plate 2.

Plate 3 shows the impact car and column shaft after the collision, the base of the shaft came to rest 5.5 m from the root and about 0.5 m from the collision path of the car. The damage to the car was negligible. A deceleration record was not obtained during this particular test but judging from the small amount of damage sustained by the car the peak deceleration is not likely to have been greater than 10 g. Fig. 1 is a record of the tension in the suspension cable in front of and behind the test column. The peak tensions recorded in the two spans were 15,000 N and 13,000 N occurring at one and a half seconds after impact.

4. HIGH SPEED TEST

4.1 Object of the test

The high speed test was designed to test the successful cable arrangements of the low speed test No. 3 in a more complete arrangement with a full speed 70 mph impact. At this test speed the set-up was made consistent with that which might be used on the central reservation of a dual carriageway.

4.2 Test installation

For the high speed test an installation of five 12 m lightweight breakaway columns (the centre one used as the impacted column) was erected at an angle of 15° to the centre line of the Long
Straight of the Road Research Laboratory test track. A spacing of 45 m was chosen to allow for the impacted column only to be on the test track, adjacent columns being on the hard shoulder. This arrangement allowed the simulation of a car leaving the carriageway and crossing the central reserve of a dual carriageway at this angle. Plate 4 shows three of the columns of the test installation, the one in the foreground being the test column. The torque on the flange bolts on all the columns was set at 40 Nm.

After the columns were erected the suspension cable with strain gauges fitted in each span was lifted into position on the shoulder of the fitting used in the low speed test No. 3 (see Plate 2) and tensioned until the sag in each span was approximately 0.30 m, the tension then being approximately 2700 N. The suspension cable was then attached to the fitting by a short length of cable as in Plate 2.

4.3 Impact car

The impact car was a standard model of a 1.5 litre saloon weighing 1100 kg including control and recording equipment. The equipment for steering and braking the impact car was operated by remote control from a command car which followed the impact car (see Plate 5). Steering was by means of a servo-drive to the steering wheel which responded to movements of a control carried in the command car.

4.4 Recording and photographic equipment

Accelerometers fitted to the chassis of the impact car measured decelerations which were recorded on photographic paper by a recorder carried in the boot. In addition a 100 Hz trace and an impact signal were recorded. The outputs from the strain gauges in the suspension cable were taken to a galvanometer recorder in the building on the left of Plate 4. The speed of the impact car was measured by timing its passage over two pneumatic tubes 3.05 m apart, fixed to the ground just in front of the test column.

High speed cine records were made of the motion of the car and columns during the collision and still photographs were taken before, during, and after impact.

4.5 Test procedure

The equipment in the impact car and command car having been finally checked, the impact car was pushed up to a speed of 40 km/h with top gear engaged, a predetermined throttle setting and the ignition switched on. The impact car then accelerated under its own power and was steered by an operator in the command car. When the impact car was about 150 m from the test column the recorder was switched on and the command car was slowed down to a stop in the next 100 m, steering control of the impact car being maintained until it had collided with the test column. Immediately after the collision the ignition of the impact car was switched off and its brakes were applied by signals from the command car.
5. RESULTS

5.1 Deceleration record of the impact car

The deceleration record of the impact car during the collision is shown in Fig. 2. The peak deceleration was 5.8 g occurring 0.015 seconds after impact. The duration of the collision was 0.06 seconds the mean deceleration being 1.9 g. The calculated reduction in speed due to the collision was 4.0 km/h, the initial speed as measured by the pneumatic tube detectors being 111 km/h.

5.2 Behaviour of and damage to the impact car

The impact car struck the test column half way between the centre line of the bonnet and the near side front wing as shown in Plate 5. After the collision the impact car veered slightly to the left and travelled 84 m before coming to rest under the action of the brakes.

The damage to the impact car was confined to the relatively soft metal work of the bonnet, near side wing and bumper (see Plate 6). It should be noted that this car had undergone at least three previous impact tests and the soft metal work had been beaten out and certain joints rewelded. The damage resulting from the present test is therefore likely to be greater than it would have been in a previously undamaged car. No damage occurred to the steering mechanism or engine. The damage index\(^{(5)}\) was estimated as follows :-

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<td>Heavy superstructure</td>
<td>260</td>
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<tr>
<td>Light chassis</td>
<td>90</td>
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<td>350</td>
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<td><strong>Ratio of damage index to car weight (cwt)</strong></td>
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In a previous test in which this type of car collided with a 12 m light weight breakaway column which was not restrained at the top the damage index/car weight\(^{(1)}\) ratio was 1.5.

5.3 Behaviour of and damage to the test column and suspension cable

In the collision the breakaway joint functioned satisfactorily. The bottom end of the shaft of the column was projected forwards and upwards and a bending failure occurred about 2 metres from the joint flange where a design change in thickness of the column wall to reduce the weight of the column takes place (see Plate 5). The top end of the shaft and bracket arm fell vertically until the column assumed a horizontal position at a height of 3.5 m above ground 0.6 secs after impact, the deflection of the suspension cable being approximately 8 m. The maximum tensions recorded in the suspension cable were 25,800 N in the span on the impact side of the test column and 24,000 N on the side remote from the impact.

During the subsequent upward movement of the suspension cable the column rotated about its longitudinal axis and the bracket arm passed over the suspension cable. The lantern was thrown off the bracket arm during this rotation. The shaft of the column finally came to rest in the position shown in Fig. 7 and 8, the butt end projecting to an extent that would have obstructed
90% of the fast lane of the opposite carriageway. The final deflection of the suspension cable was approximately 3 m.

A check on the flange bolt torques on all the breakaway joints after the collision showed no change in the two columns remote from the test column. On the column next to the test column on the impact side the torque was maintained on two of the bolts but was reduced to zero and 12 Nm respectively on the other two. The bolt torques on the column on the side away from the impact were reduced to zero on three bolts and 20 Nm on the fourth bolt.

6. DISCUSSION

6.1 Severity of the collision

In the present test the severity of the damage to the impact car as estimated by the damage index/car weight (cwt) ratio (5) gave a figure of 16. A previous test in which the same type of car collided at a speed of 100 km/h with a column of the same type without the suspension cable resulted in a damage index/car weight ratio of 1.5.

An estimate of the severity of injuries likely to be suffered by drivers can be derived from the results of a study of the relationship between damage index/car weight (cwt) ratio and severity of injuries to drivers which showed that the above value of 16 was found to be associated with fatal serious and slight injuries in three, fifteen and thirty seven per cent of accidents respectively in which cars struck single vehicles or obstacles. A damage index/car weight (cwts) ratio of 1.5 however would result in no injuries.

For comparison with the above collisions with breakaway columns, a damage index/car weight ratio of 51 resulted from a collision with a conventional tubular steel column at a speed of 68 km/h. This figure would be associated with twenty one, forty two and thirty two percent of fatal serious and slight injuries to drivers.

6.2 Head impact velocity

It has been estimated that if a human head strikes the windscreen or a solid part of a vehicle with a velocity less than 18 km/h there is only slight risk of serious head injury(6). Assuming that the head of an unrestrained occupant of the impact car was initially at a distance of 0.46 m from the windscreen the deceleration record in the present test (Fig. 2) indicates that the velocity with which the head would strike the windscreen would have been about 4 km/h. The risk of serious head injury would therefore have been very low. This estimate of severity however cannot be related to that in the previous section, as injuries other than to the head were taken into account in the damage index/car weight study of accidents. Both methods of assessment however show that the risk of serious injury in the collision would be low.

6.3 Performance of the test column

The performance of the breakaway joint in the collision was not affected by the attachment of the top of the column to the suspension cable but the damage to the car was increased compared to that produced by a similar collision with an unrestrained breakaway column of the same type.
However, if the column had been mounted in a position less than 2 m from the opposing carriageway, the motion of the column during the collision and its final position would have resulted in this carriageway being slightly obstructed. (See Plate 8).

The damage to the shaft of the column shown in Plates 7 and 8 would necessitate complete replacement although the root section was undamaged. It would appear from the reduced bolt torques on adjacent columns that the bolts on these columns would need to be replaced after a collision.

In an actual installation it is not anticipated that the shaft would be re-used after a collision and in installations erected up to the present, spare shafts and bolts are kept in stock, hence replacement should be relatively simple.

6.4 Design of the lightweight breakaway column

As mentioned in Section 2 of this report no allowance has been made for wind loads on the suspension cable in calculating cable size. This load will also need to be considered in relation to the design of the breakaway column. The present design of the RRL lightweight breakaway column is such that it will meet the requirements of the British Standard Specification for both steel and aluminium columns (7) (8) taking into consideration the wind loads on the shaft, bracket arm, and lantern. The extra wind loads imposed on the column due to the suspension cable is likely to result in it not meeting the requirements of the above standards particularly in the situation when icing of the cables occurs. It would therefore be advisable for the design of the column to be examined taking into account this extra load.

7. CONCLUSIONS

It is concluded that a suspension cable can be attached to the tops of the columns in a breakaway column installation so that a column struck in a collision by a car at speeds up to 110 km/h will not fall to the ground. In addition the restraint put on the column does not unduly increase, (a) the damage to the car or (b), the risk of serious injury to the occupants.

In low speed impacts the butt end of the column would fall back to the ground behind the car and in itself would present no further hazard.

In high speed collisions up to 110 km/h the lower end of the column is projected upwards and forwards allowing the car to pass underneath. However, due to the subsequent rotation of the shaft and the large final deflection of the suspension cable there is a risk after a collision of the lower end of the shaft of the column obstructing the opposite carriageway if used on a central reserve of 4 m or less in width. It also appears that adjacent columns would need to be examined and the flange bolts to be changed.

This system of suspended breakaway columns might be satisfactory for use on roads where pedestrians are present, with limitation due to cable suspension problems at junctions and with reservations about aesthetic acceptability. This type of installation would be satisfactory on the verges of high speed roads if there was a specific need to prevent the columns from falling.
8. ACKNOWLEDGEMENTS

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This report was prepared in the Driver Aids and Abilities Section of the Safety Division of RRL.

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Fig 1. RECORD OF TENSION IN SUSPENSION CABLE FOR LOW SPEED TEST No. 3
Fig. 2. DECELERATION RECORD FROM CAR DURING THE HIGH SPEED COLLISION WITH SUSPENDED BREAKAWAY COLUMN
Attachment of suspension cable to column
PLATE 3

Car and column after low speed collision test No. 3
PLATE 4

Part of the installation for the high speed test
PLATE 7

Final position of test column after high speed collision
ABSTRACT


Low speed and high speed collision tests have been carried out to investigate the feasibility and effectiveness of connecting the tops of breakaway columns by a steel suspension cable so that after a collision the shaft of the column involved is left suspended between the two adjacent columns, and does not fall onto the carriageway or footpath.

The tests showed that a suspension cable can be easily attached to the tops of breakaway columns, and the restraint put on the columns does not significantly increase the damage to the car or the risk of serious injury to occupants.

Due to the large final deflection of the suspension cable there is a risk of the lower end of the column obstructing the opposite carriageway after a collision if this type of installation without barriers is used on a 4 m central reserve of a dual carriageway road. It also appears that after an impact adjacent columns would need to be examined and the flange bolts changed.