General

Collision exposure is usually greater along horizontal curves than along tangent sections of a highway. The potential for collisions is significantly increased when the safe travelling speed along a curve is below the posted speed along a tangent segment of the highway.

The safe travelling speed at which a curve may be negotiated is normally established through ball-bank indicator testing.

The established advisory speed must be both realistic and safe, meeting drivers' expectations for a given set of geometric, operational, and environmental conditions. Motorists are advised about safe speeds along curves through the use of an Advisory Speed tab.

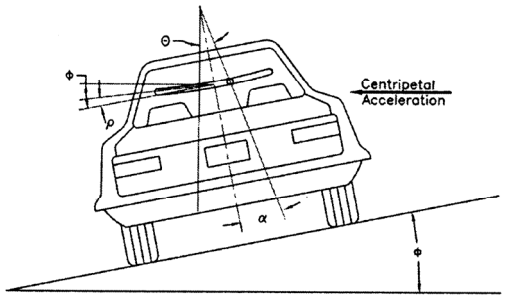
Ball-Bank Indicator Testing

Ball-bank indicator testing is the most common and practical way of determining advisory speeds on curves.

During testing, the device is mounted in a vehicle and ball-bank readings are taken at different speeds along a curve to determine safe travelling speed.

The centripetal acceleration developed as a vehicle travels at a uniform speed on a curve causes the ball to roll out to a fixed angle.

At any time, the ball-bank reading indicates the combined effect of a body roll, lateral acceleration angle, and superelevation as shown in Figure 1.



α = Ball Bank Indicator angle
ρ = Body roll angle
Φ = Superelevation angle
Θ = Centripetal acceleration angle

Figure 1 – The effect of the centripetal acceleration acting on a vehicle while traveling along a curve.

Usually several readings are taken at different speeds until a satisfactory speed-angle combination is obtained.

An example of a ball-bank reading is illustrated below in Figure 2.

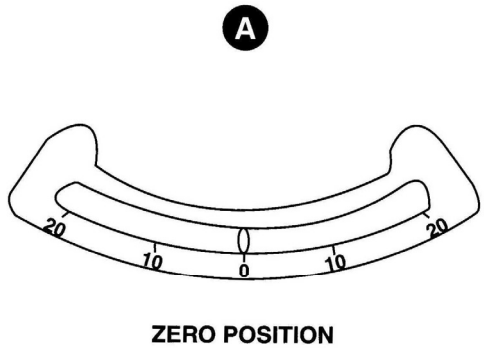


Figure 2 - A display with ball-bank indicator readings.

Table 1 shows the maximum ball-bank reading to be used when determining the maximum safe operating speed.

Table 1

Maximum Ball-Bank Reading	Maximum Safe Operating Speed (Paved surfaces)
10°	Speeds 55 to 100 km/h may be accommodated.
12°	Speeds 40 to 50 km/h may be accommodated.
14°	Speeds 30 km/h or less are accommodated. Curve should be signed for the speed at which the reading occurs.

Source: AASHTO *Policy on Geometric Design of Highways and Streets*

Note: The applicable ball-bank reading should be reduced by one (1°) degree for gravel surfaces.

Types of Ball-Bank Indicators

The two most common types of ball-bank indicators are a manual and electronic indicator.

Figure 3 - Example of a Manual Ball-Bank Indicator

A manual ball-bank indicator consists of a steel ball in a sealed glass tube. Except for the damping effect of the liquid in the tube, the ball is free to roll.

Figure 4 - Example of an Electronic Ball-Bank Indicator

The electronic ball-bank indicator unit has a digital angle display in degrees and often has a feature that allows for the transfer of data to a personal computer.

More information on ball-bank indicator testing is provided in engineering handbooks such as the *Traffic Engineering Handbook* or AASHTO *Policy on Geometric Design of Highways and Streets*.

Testing Procedure

During testing, the ball-bank indicator is mounted to the dashboard with rubber suction cups or by other stable methods. The device position is then adjusted to allow the ball to rest freely at zero degrees when the vehicle is standing on a level surface (i.e., on a tangent section).

Vehicle movement around a curve causes the ball to swing from the zero position (e.g., vehicle movement to the left causes the ball to swing to the right). The faster the vehicle moves around the curve or the sharper the curve, the greater the distance the ball swings away from the zero degree position.

The following steps should be considered during the testing procedure:

1) Testing should start well in advance of the curve being evaluated. The driver should enter the curve at a predetermined speed and should try to maintain the assumed speed throughout the curve. If possible, the car should be centered on a travel lane and driven as parallel as possible to the roadway centerline.
2) The first trial run should be made at a speed somewhat below the anticipated maximum safe speed. Subsequent trial runs are conducted at 10 km/h speed increments.
3) The curve should be driven a number of times until at least two matching ball bank readings (i.e., number of degrees) are obtained for each direction of travel. Testing should be conducted separately for each direction of travel.

Establishing Advisory Speed on a Curve

When establishing final advisory speed, consideration should be given to other factors which may be influencing the operation of vehicles around the curve. These factors include geometric conditions (e.g., available sight distances, presence of intersections, obstructions along the road), predisposition to certain collision types (e.g., run-off-road), traffic distribution (e.g., presence of trucks), environmental conditions (e.g., presence of lighting) and other site-specific operational conditions.

An advisory speed that is too high compromises safety because it increases

the potential for collisions (vehicle stability is impacted). An advisory speed that is too low may result in less driver compliance.

If lower advisory speeds are frequently exceeded by drivers without a risk, problems may arise at locations where curves are severe and the safety margin is reduced.

The average roadway operational and environmental conditions, which the advisory speed is going to represent, also have to be taken into consideration. Dry pavement provides better resistance than wet pavement against the centrifugal force encountered on curves. Also, vehicle characteristics have to be considered (i.e., trucks have a higher centre of gravity, which creates a higher potential for a vehicle roll over).

In general, advisory speeds based on conservative ball-bank indicator readings are sufficiently low to safely accommodate trucks and wet pavement conditions.

Ball-bank indicator testing and establishing safe travelling speed on a curve should be performed by qualified personnel. Proper documentation should also be provided for any future reference.

References to Standards

Recommended Practices Section: Warning Signs	Turn and Curve Signs Reverse Turn and Reverse Curve Signs Winding Road Sign
ITE	Traffic Engineering Handbook
AASHTO	Policy on Geometric Design of Highways and Streets.

CURVE ADVISORY SPEED – BALL-BANK INDICATOR TESTING
CURVE STUDY SHEET

Location:

Road:	**Region/District:**
Radius of Curve (m):	**Length of Curve (m):**
Posted Speed (km/h)	**Existing Traffic Signs:**

Pavement Type:	**Width:**	**Condition:**

Observer:

	TRIAL NO.	BALL-BANK ANGLE FOR VARIOUS TRIAL SPEEDS								SUPER ELEVATION	RECOMMENDED SPEED
		___0 Km/h	___5 Km/h	___0 Km/h	___5 Km/h	___0 Km/h	___5 Km/h	___0 Km/h	___5 Km/h		
BOUND ____	1										
	2										
	3										
	SPEED AT	10^0 BALL-BANK ANGLE =									
		12^0 BALL-BANK ANGLE =									
		14^0 BALL-BANK ANGLE =									

	TRIAL NO.	BALL-BANK ANGLE FOR VARIOUS TRIAL SPEEDS								SUPER ELEVATION	RECOMMENDED SPEED
		___0 Km/h	___5 Km/h	___0 Km/h	___5 Km/h	___0 Km/h	___5 Km/h	___0 Km/h	___5 Km/h		
BOUND ____	1										
	2										
	3										
	SPEED AT	10^0 BALL-BANK ANGLE =									
		12^0 BALL-BANK ANGLE =									
		14^0 BALL-BANK ANGLE =									

REMARKS:

CURVE ADVISORY SPEED – BALL-BANK INDICATOR TESTING
CURVE STUDY SHEET – EXAMPLE

Location: Km 46.8

Road: Hwy 40:36	**Region/District: Grande Prairie**
Radius of Curve (m): 380 m spiral	**Length of Curve (m): 633 metre**
Posted Speed (km/h): 100 km/h	**Existing Traffic Signs: Curve Sign**

Pavement Type: A.C.P.	**Width: 11.0 m**	**Condition: good**

Observer:

	TRIAL NO.	BALL-BANK ANGLE FOR VARIOUS TRIAL SPEEDS								SUPER ELEVATION	RECOMMENDED SPEED
		80 Km/h	85 Km/h	90 Km/h	95 Km/h	100 Km/h	___5 Km/h	___0 Km/h	___5 Km/h		
___NORTHBOUND	1	7		10	12	15					
	2	6		10	11	13					
	3	7		10	11	14					
	SPEED AT				10^0 BALL-BANK ANGLE = 90						
					12^0 BALL-BANK ANGLE = 95						
					14^0 BALL-BANK ANGLE = 100						

	TRIAL NO.	BALL-BANK ANGLE FOR VARIOUS TRIAL SPEEDS								SUPER ELEVATION	RECOMMENDED SPEED
		80 Km/h	85 Km/h	90 Km/h	95 Km/h	100 Km/h	___5 Km/h	___0 Km/h	___5 Km/h		
___SOUTHBOUND	1	7			10	12					
	2	7			10	12					
	3	6			10	13					
	SPEED AT				10^0 BALL-BANK ANGLE = 95						
					12^0 BALL-BANK ANGLE = 100						
					14^0 BALL-BANK ANGLE =						

REMARKS: Northbound the alignment has horizontal curve and a sag curve at the same location. Recommend to put up 85 km/h speed tab.