

“Creating affordable & reliable roads”





Health issues raised by poorly maintained road networks

**Hi folks,
Now listen carefully to Steve.
If you ´re into Rock ´n Roll,
then you ´ll appreciate this
slideshow from the Beaver Road!**



Task leader: Johan Granlund
Swedish Road Administration, Consulting Services



Yet a tragedy at the Beaver Road



Last Monday, 20th Oct:

Car driver killed by HGV, skidding on slippery “Black ice” at the Beaver Road 331.



Outline



Northern Periphery project partners in Roadex III .

Health and safety aspects on ride vibration.

10 truck roundtrips of the 280 km Beaver Road:

- **Truck ride vibration above the EU Action Value.**
- **Bumps gave high compression stress in the spine.**
- **Intense roll vibration at Hazardous Sites,
caused by Rut Bottom Cross Slope Variance.**

Safety issues related to improperly banked curves.



The EU Northern Periphery – A good piece!





Roadex III partners

-Creating affordable and reliable roads



	SRA Northern Region, Lead Partner Swedish Forest Agency	 Vägverket	 SKOGSSTYRELSEN SWEDISH FOREST AGENCY
	FINNRA, Savo-Karjala District		 FINNISH ROAD ADMINISTRATION
	The Municipality of Sisimiut		
	The Icelandic Public Roads Administration		 VEÐAGERÐIN
	NRA Northern Region		
	The Highland Council, Forest Enterprise, The Western Isles Council	 The Highland Council The Highland Council The Highland Council	 Forest Enterprise 



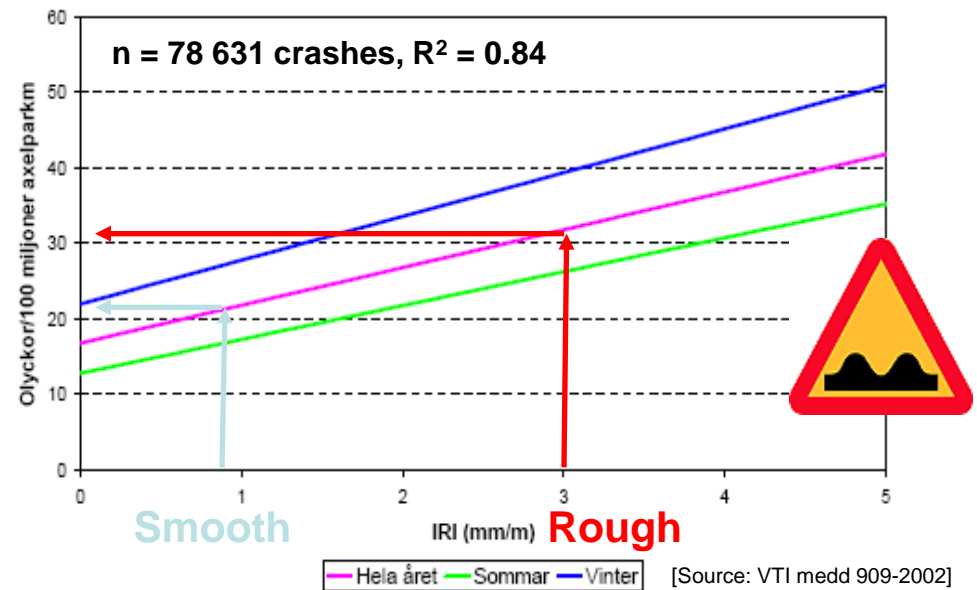
Disproportionate health and safety risks



NP truckies suffer increased risk of stress related heart disease and back pain.

153 % higher risk to die in a crash in rural NP areas, than in the metropols Stockholm & Gothenburg.

Crash rate



Bumpy roads have more than 50 % higher crash rate



Health and safety aspects on ride vibration



Figure from the EU Guide to good practice on WBV.

Truck seat vibration often in the ISO 2631 *Health Caution Zone*.

Bounce, Pitch and Roll motions.

Roll accompanied by lateral forces / buffeting.

Frequency range 0.5 - 80 Hz.

Resonance in eye globes, spine, stomach etc.

Bumps – stressing effect.

Undulations – create drowsiness.



Tests at the *Beaver Road 331*



**A regional 170 km route across
Västernorrland County, Sweden.**

**Annual Average Day Traffic, AADT,
ranging from 350 to 2000 veh/day.
Speed limits mainly 90 and 70 km/h.**







Road user behaviour at Rd 331

**Car driver avoiding
edge deformations.**





Behaviour at Rd 331, cont'd

**Truck driver avoiding
edge deformation.**





Test partner: Brorssons Åkeri AB



14 timber logging trucks with trailers.

Each truck runs 18 hrs/day.

Four runs of 2 * 140 km daily at the *Beaver Road 331*.

Brorssons' s annual mileage on Rd 331: 2 800 000 km.



Test truck: Scania R480 164 G 6x4



**Gross Vehicle Weight 60 ton, incl trailer and 41 ton
timber payload.**

609 000 km mileage, at 3 years age.



Mounting truck ride sensors

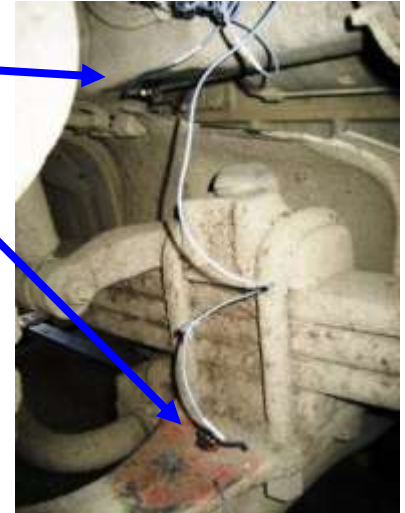
Z-axis 5 kHz at L and R frame.

Z-axis at L and R front wheel axles.

**GPS + 6-axis 100 Hz
inertial unit in the cab.**

X, Y, Z-axis 5 kHz seat pad.

**Videocamera for right of way.
(Microphone for interior noise < 5 kHz).**





Reference Measurement

A laser/inertial Profilograph scanned the test road's surface condition 20 000 times per meter



Photo: Mats Landerberg

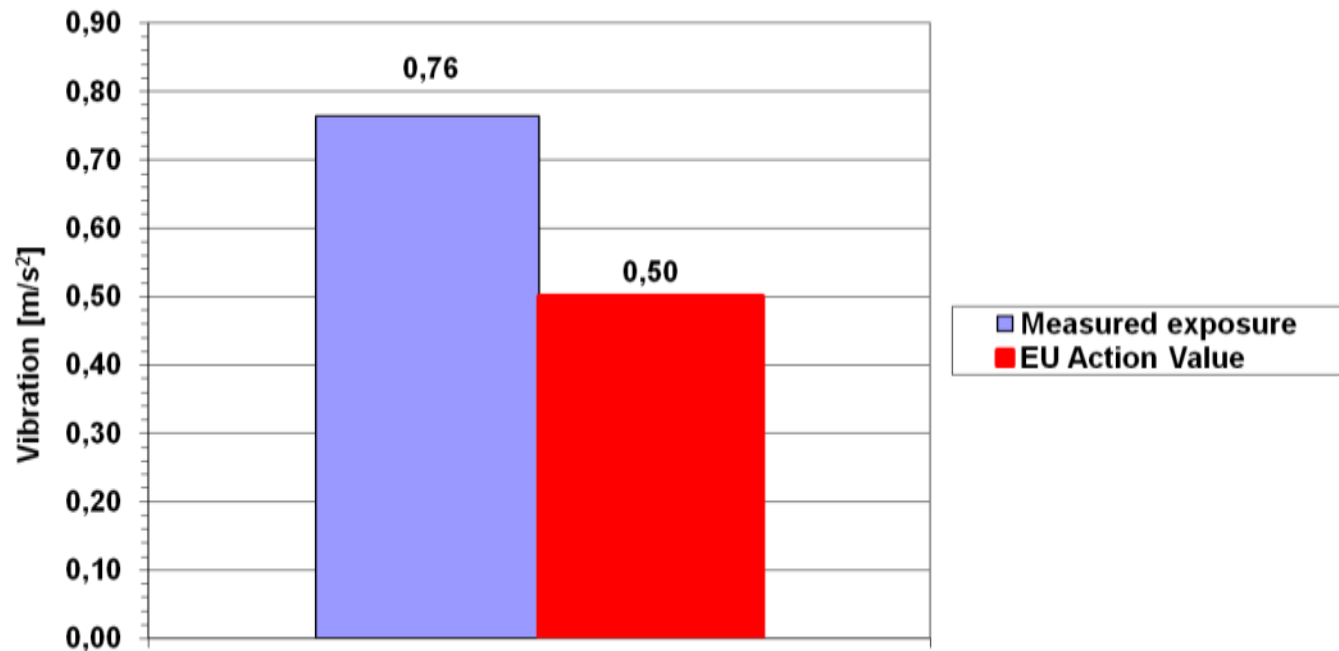


Results: 1. Daily vibration exposure $A(8)$

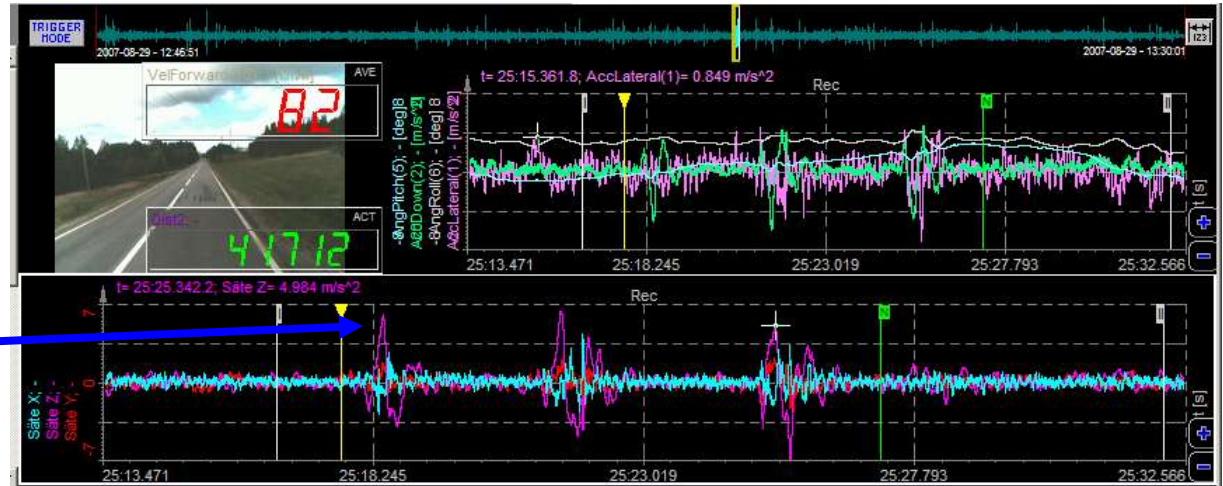
Results for normal driving shifts:

$$A(8) = 0.76 \text{ m/s}^2.$$

Exceeding the EU Action Value 0.5 m/s^2 .



2. Bumps gave high compression stress



Transient vibration may cause high compression stress in the spine; a special health risk.

The worst bumps gave $S_{ed} > 0.5$ MPa.

Exceeding this stress level corresponds to health risk, as per ISO 2631-5 (2004).



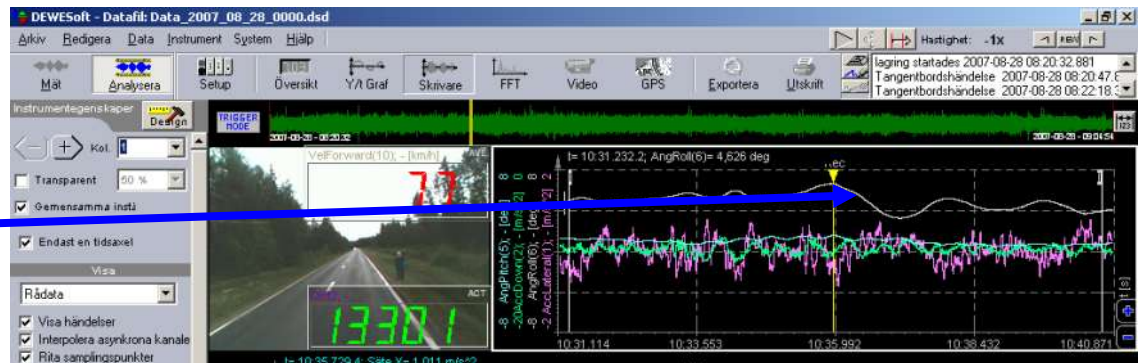
Rock n' Roll at Hazardous Site Backe

Straight road.

**Note the snake
rattling warping
between truck and
trailer.**

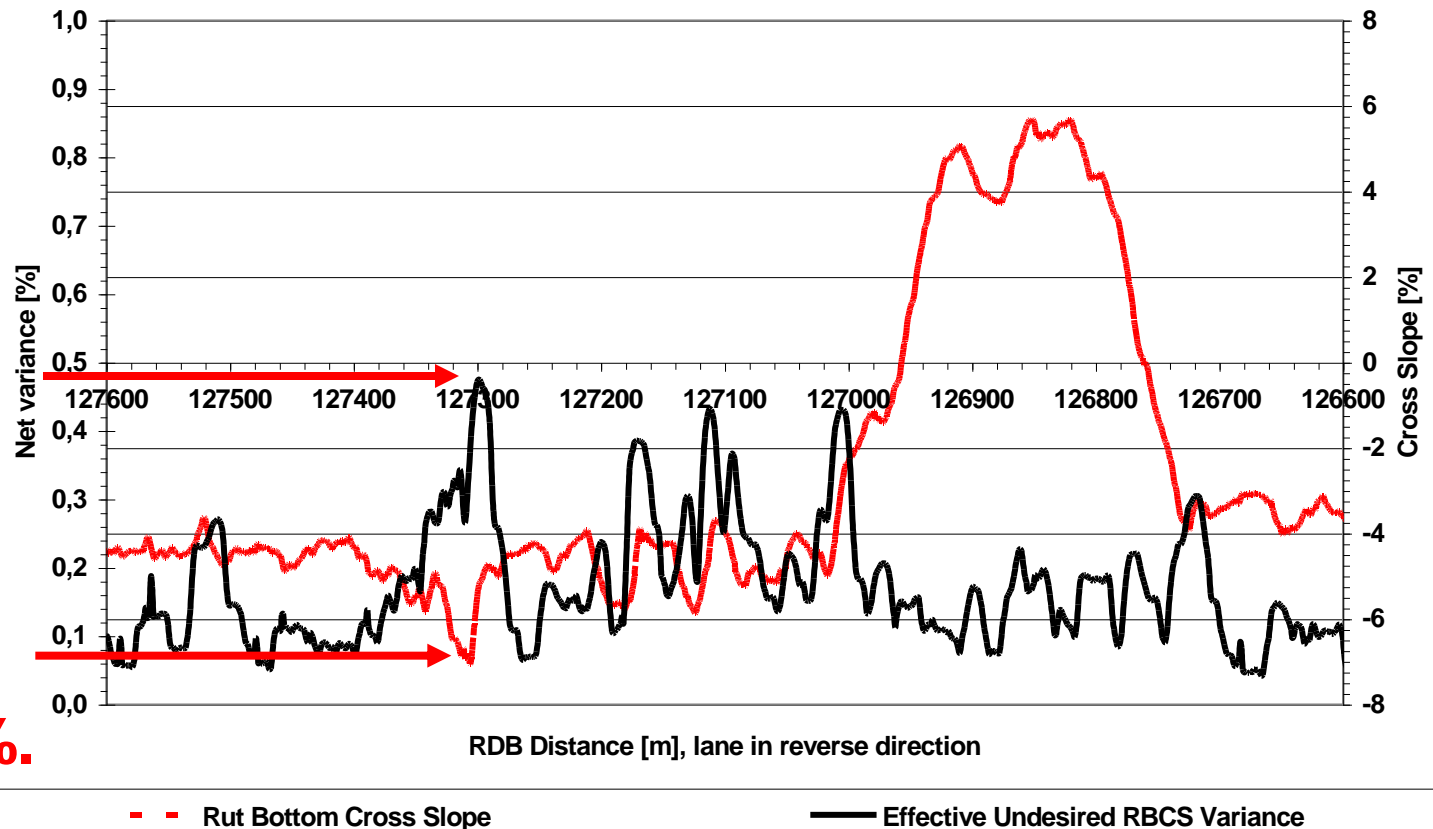


**In-truck data:
3,5°/s change in cab
roll angle**





High RBCS variance at HS Backe



Alarm!
0.47 % RBCS
variance.
Cross Slope
warps
between
-5 and -7 %.



Rock n' Roll at HS Åkerö

Straight road.

Truck cab roll angle:

**- Very high rate;
5°/s (at high freq).**

**High lateral acc in
cab: 2 m/s².**

**Very high lateral acc at
driver seat : 3.5
m/s². (+ 75 %)**





High RBCS variance at HS Åkerö

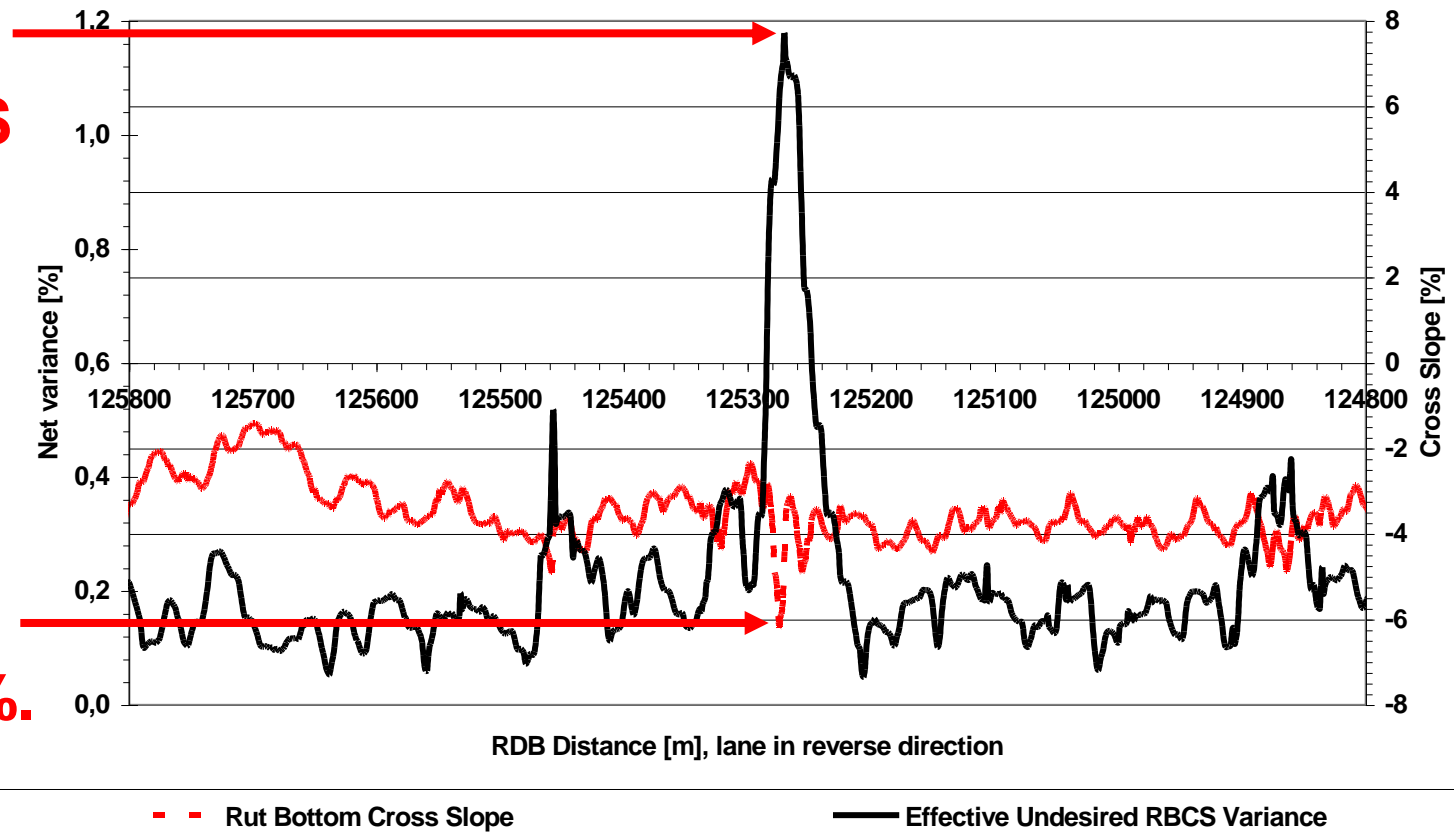
Straight road.



Alarm!

**1.18 % RBCS
variance.**

**RBCS warps
between
-3 and -6 %.**



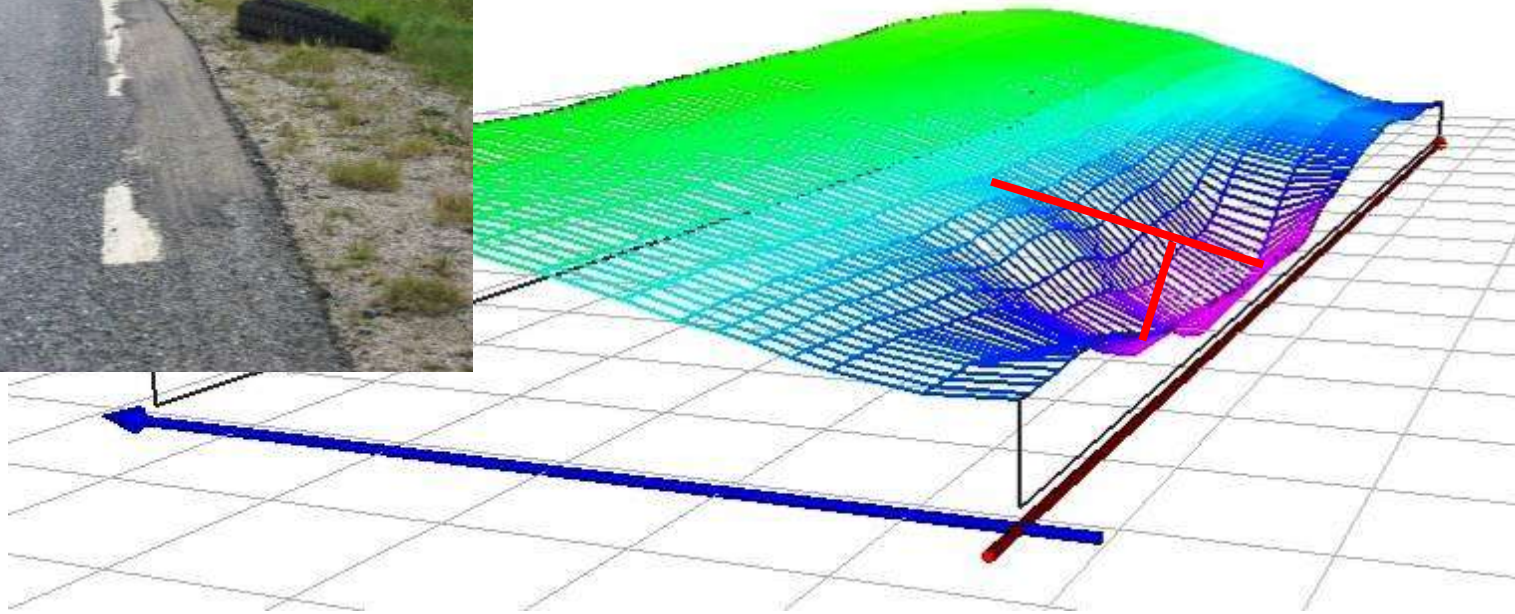


3D laserscan at HS Åkerö

Note: Exploded truck tire



**The 1.18 % RBCS variance
was caused by a 69 mm
deep deformation**





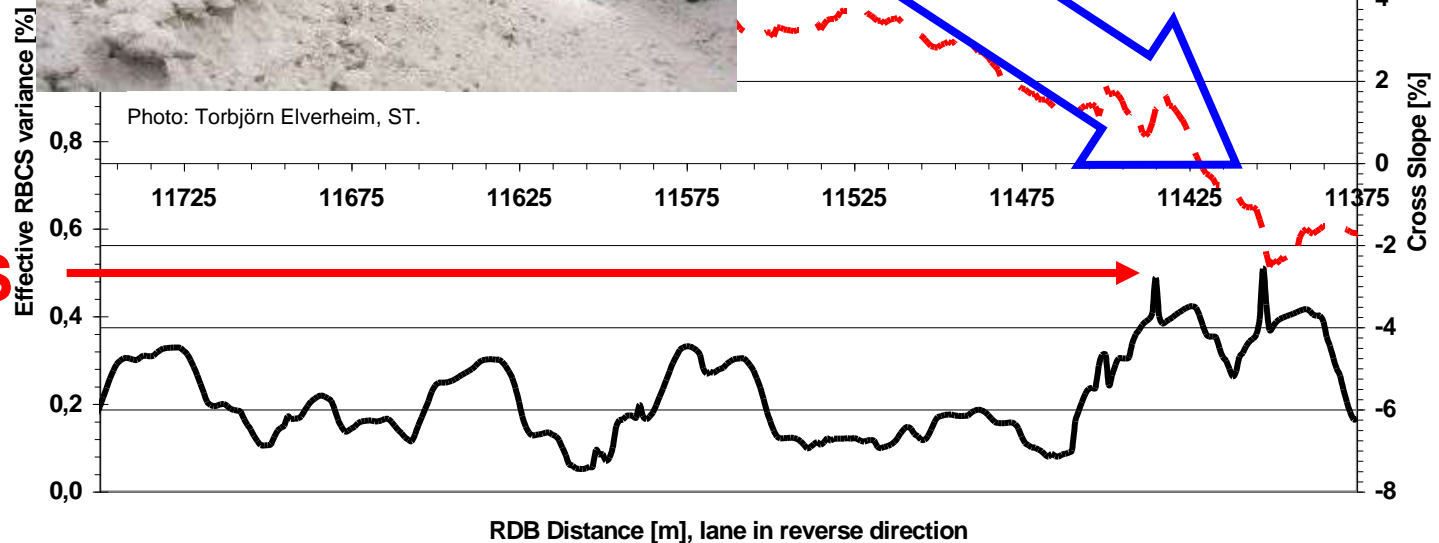
RBCS at HS Åsäng

Police: *The road surface was polished into zero friction.*



Åsäng

Ljustorp at section 11 497 m



— Rut Bottom Cross Slope

— Undesired Rut Bottom Cross Slope Variance

Alarm!
0.49 % RBCS
variance.



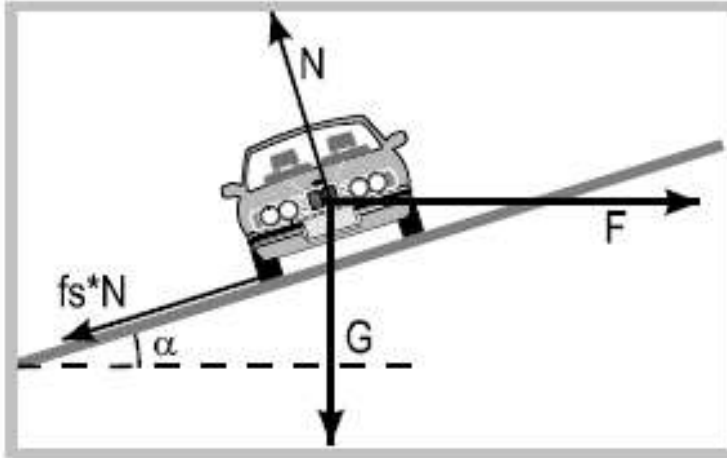
Safety issues also related to:

- Cross Slope vs Curvature.
- Drainage Gradient.





Vehicle cornering forces



$N =$	Normal force
$\tan(\alpha) =$	Cross slope
$F =$	Lateral force
$G =$	Gravity
$f_s =$	Lateral friction

[Source: VGU]

The lateral force **F** acts to pull the vehicle off the road.

F is directly proportional to the road **Curvature**; $1000 / \text{Radius}$.

The reaction forces must be larger than **F**.

Key factors:

- **Friction** (High speed & slippery surface: **Macrotexture**)
- **Cross slope** (Banking)

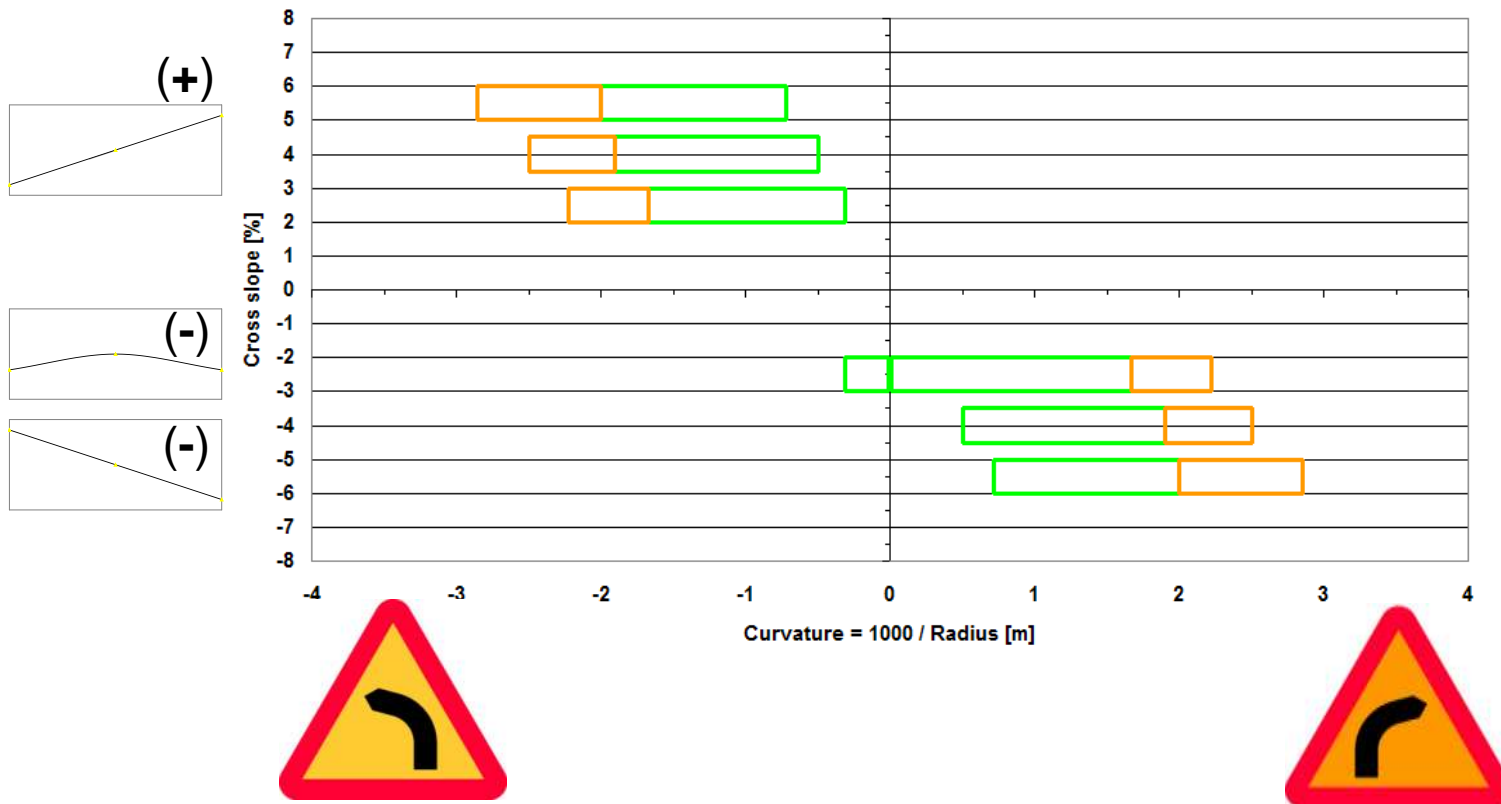


Ideal ratios for Cross Slope vs Curvature

Swedish Design Guidelines for 90 km/h.

Green box = High standard.

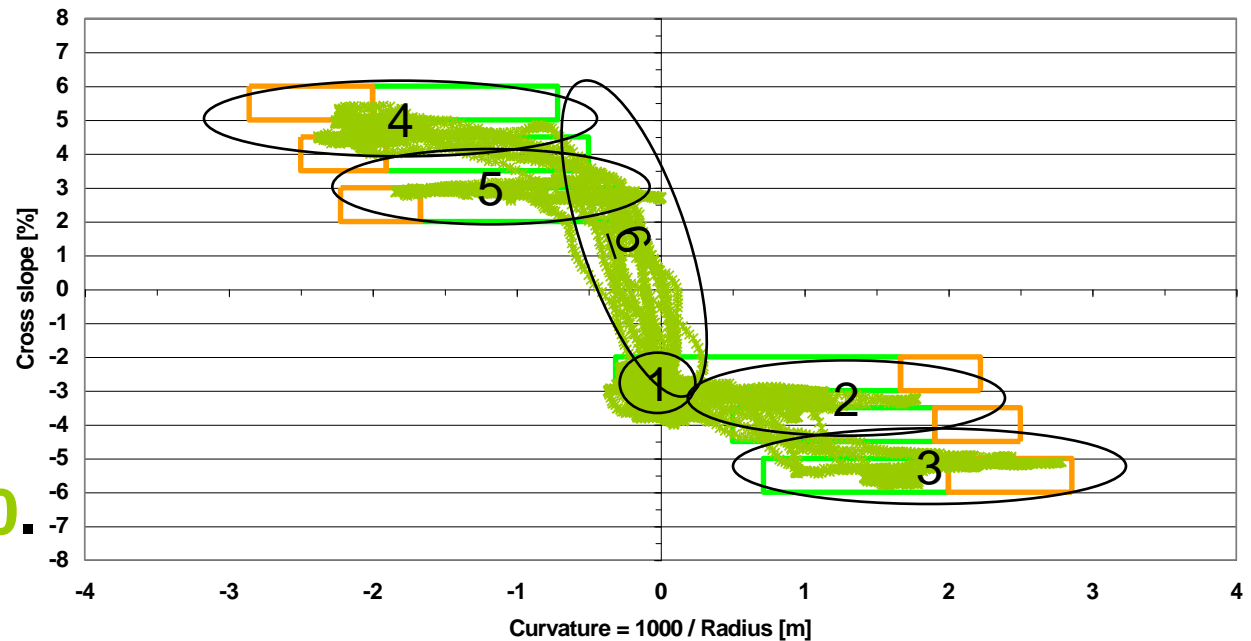
Orange box = Moderate to Low standard.





Reference Cross Slope vs Curvature

n = 12 300
reference data
(1 m per point)
from new Hw 90.



1: Straight sections

2: Wide right hand curves

3: Sharp right hand curves

4: Sharp left hand curves

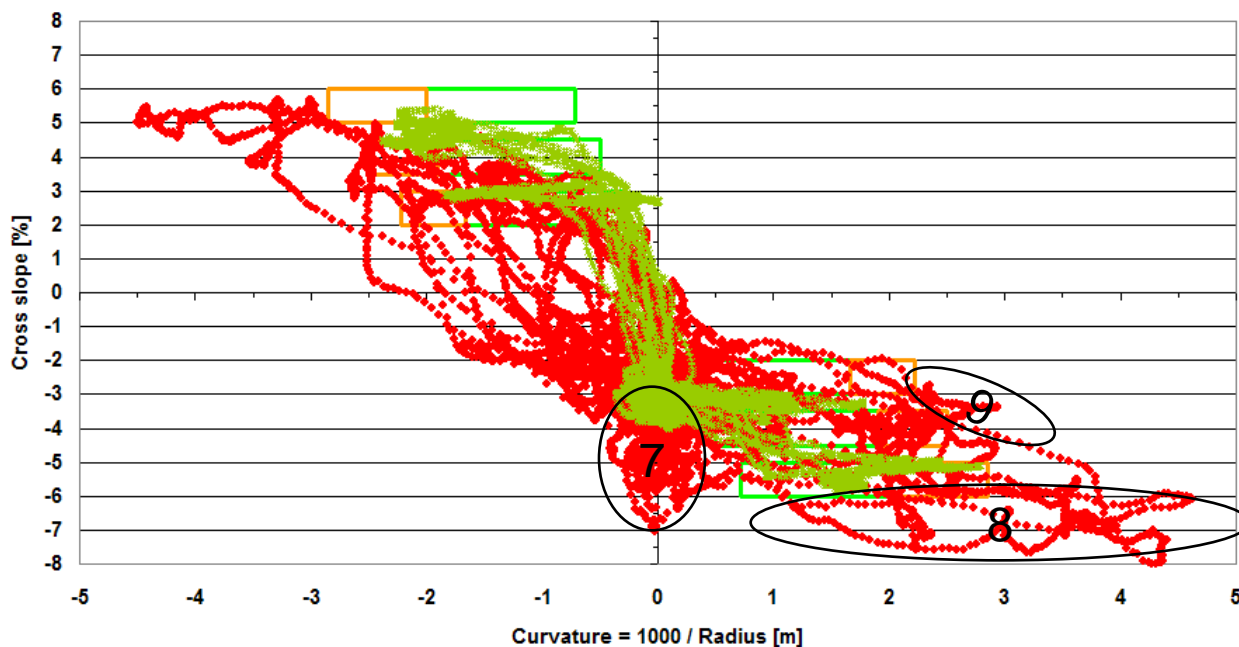
5: Wide left hand curves

6: Transitions at left hand curves



n = 12 300
sections from
old **Rd 331**.

Rd 331: Improperly banked curves



Straight sections:

7: Too much CS – uncomfortable.
Also hazardous when changing lane.

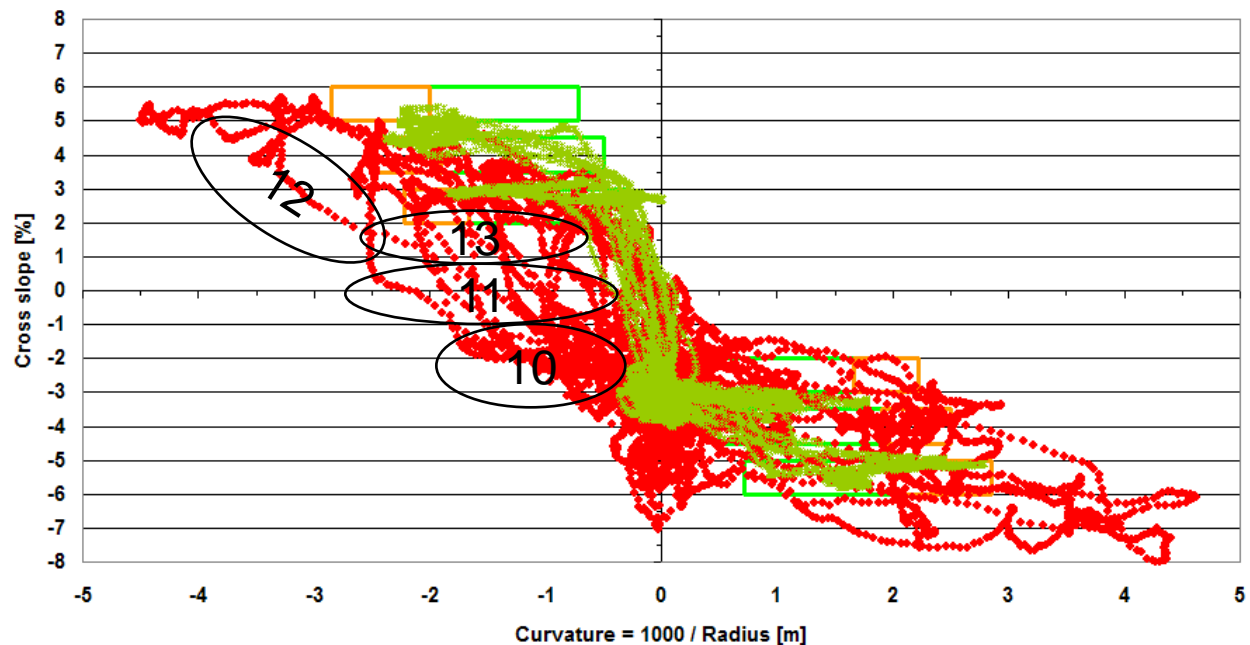
Right hand curves:

8: Too much CS – slip risk!

9: Too little CS – skid risk!



Improperly banked curves, cont'd



Left hand curves:

10: Negative CS – roll over risk!

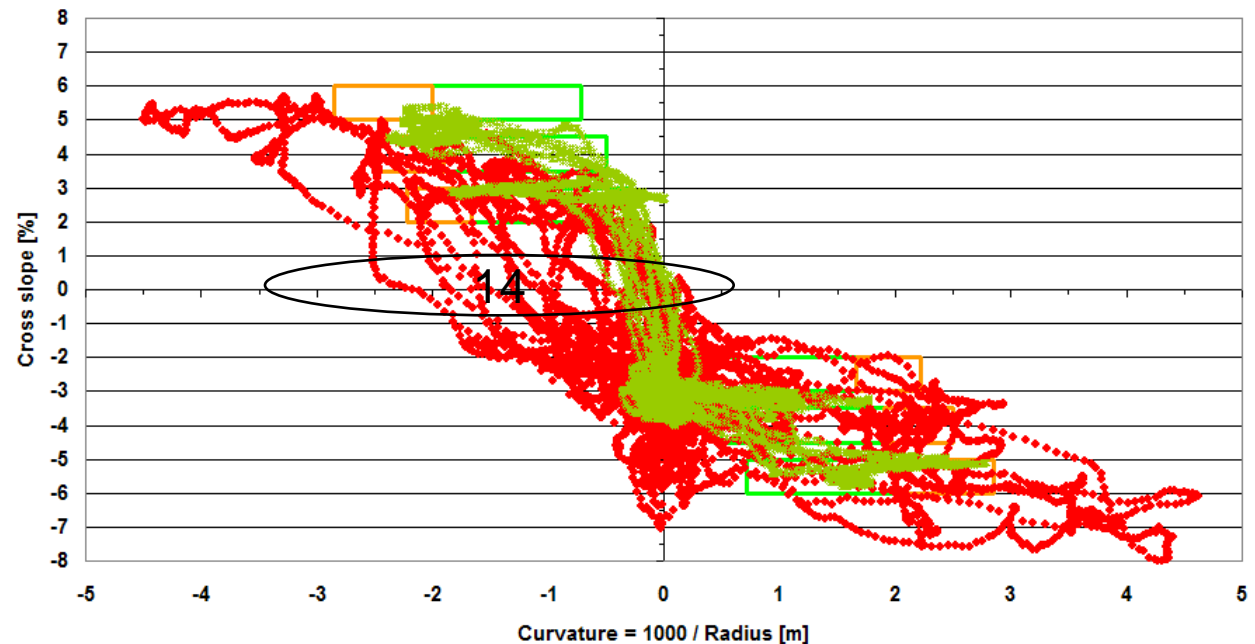
12: Too little Cross Slope – skid risk!

11: No CS – skid risk!

10 - 13: Poorly synchronized transitions



Improperly banked curves, cont'd



Transitions to / from left hand curves:

14: High skid risk - No Cross Slope!

Must have longitudinal Gradient for a Drainage Gradient > 0.5 %

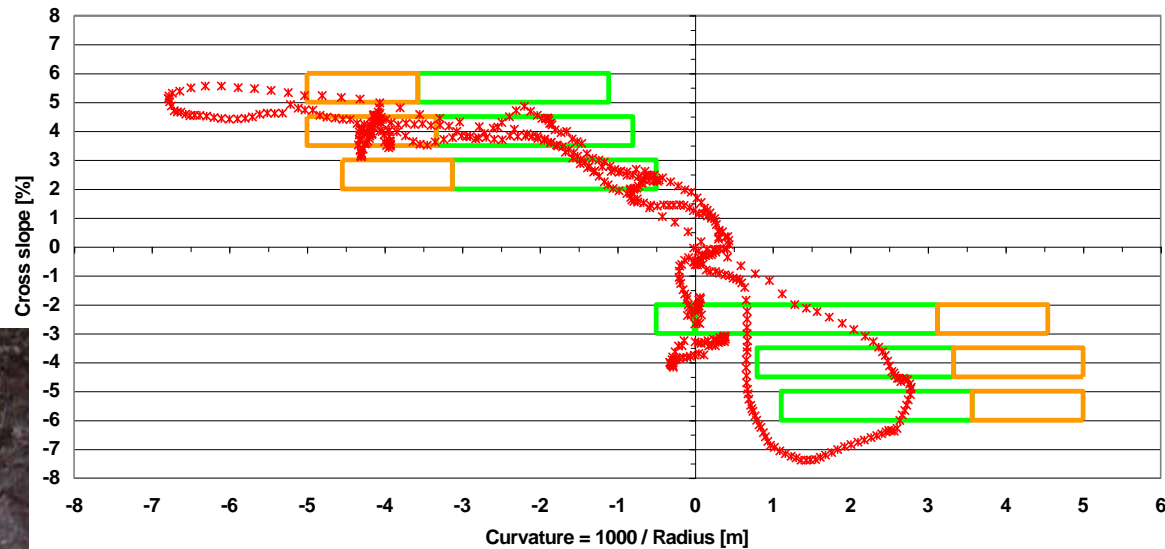


Hazardous Site Viksjö S

Lethal crash in Viksjö
*23 year driver died when
his heavy truck crashed
into rift*

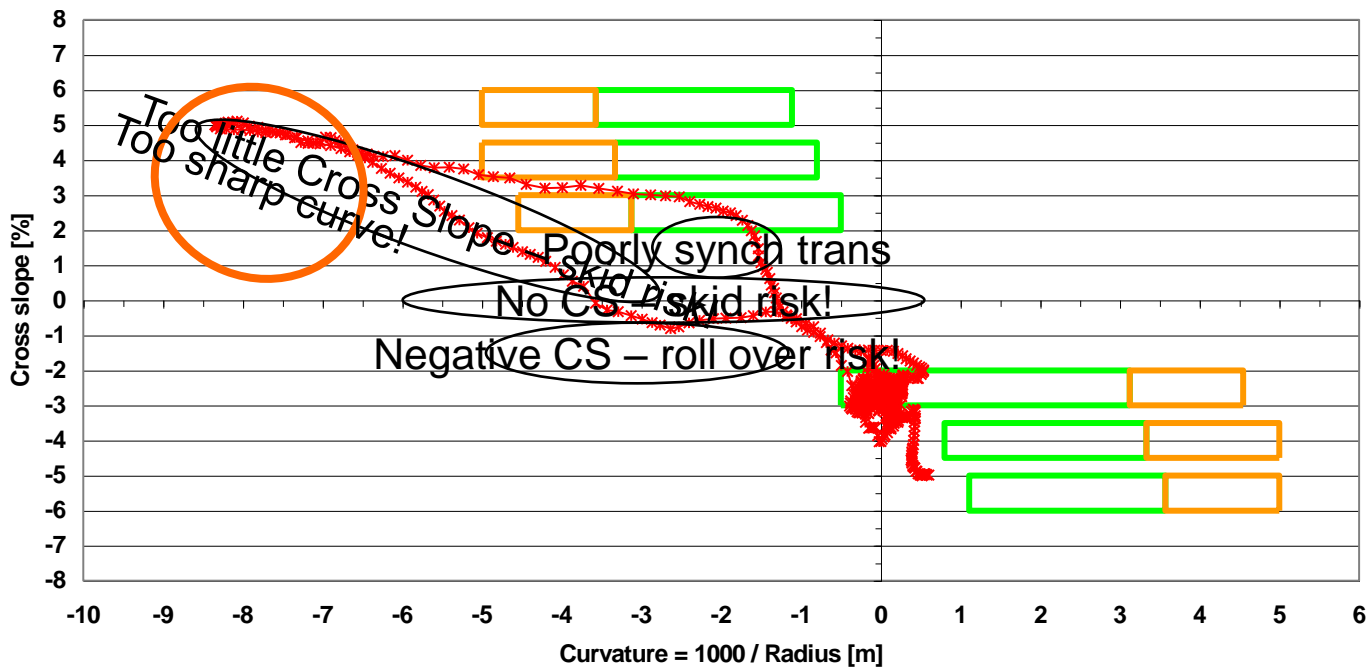


Photo: High Coast Rescue
Dept





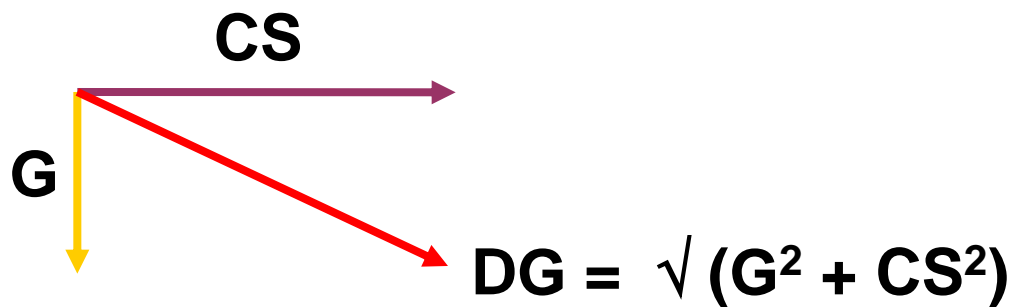
Hazardous Site Roos Curve





Low Drainage Gradient

Drainage Gradient (DG) is the resultant of Cross Slope (CS) and longitudinal Gradient (G).



**Risk areas are where CS pass 0 % (zero) and change sign:
This occurs at **entrances and exits of left* hand curves.****



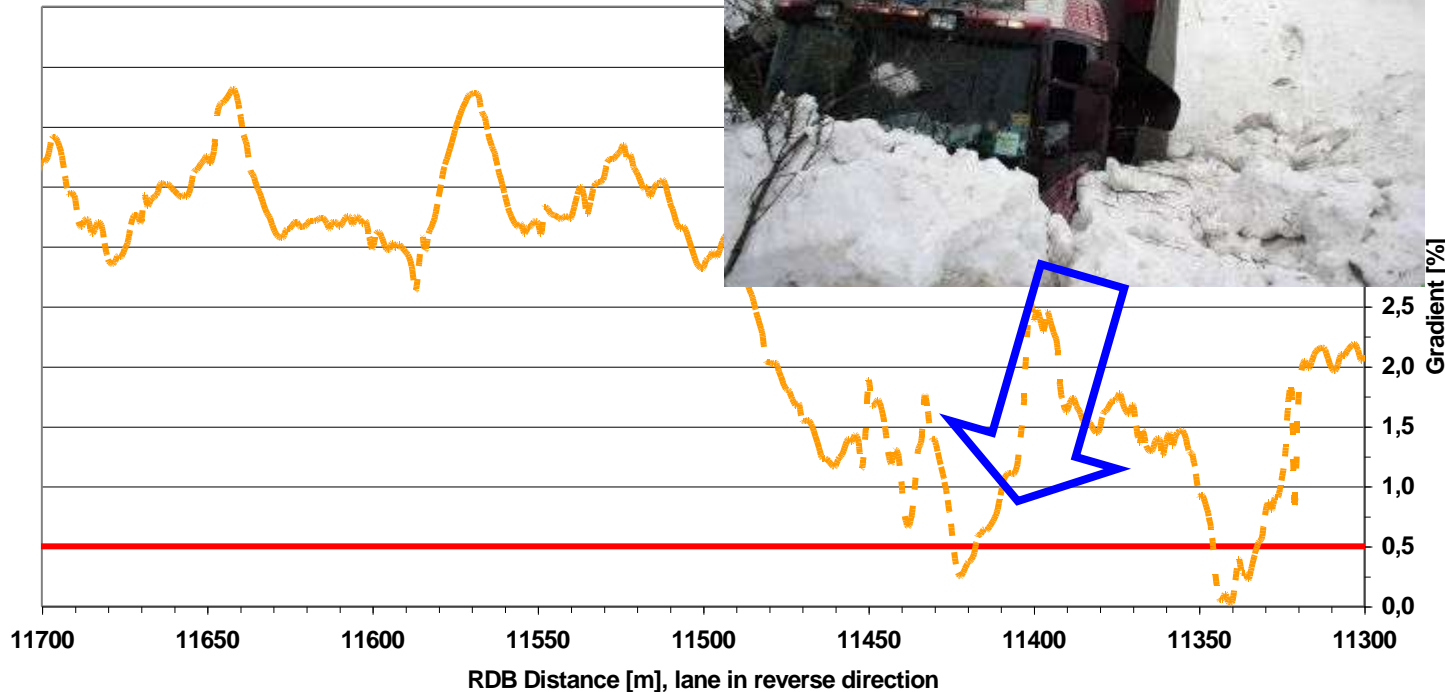
Hazardous Site Åsäng

Rd 33
Junction with Rd 703 bound



Driver: *The truck didn't respond to either steering nor braking.*

Exit from left hand curve.



— Unacceptably low Drainage Gradient

- - Drainage Gradient

Photo: Torbjörn Elverheim, ST.



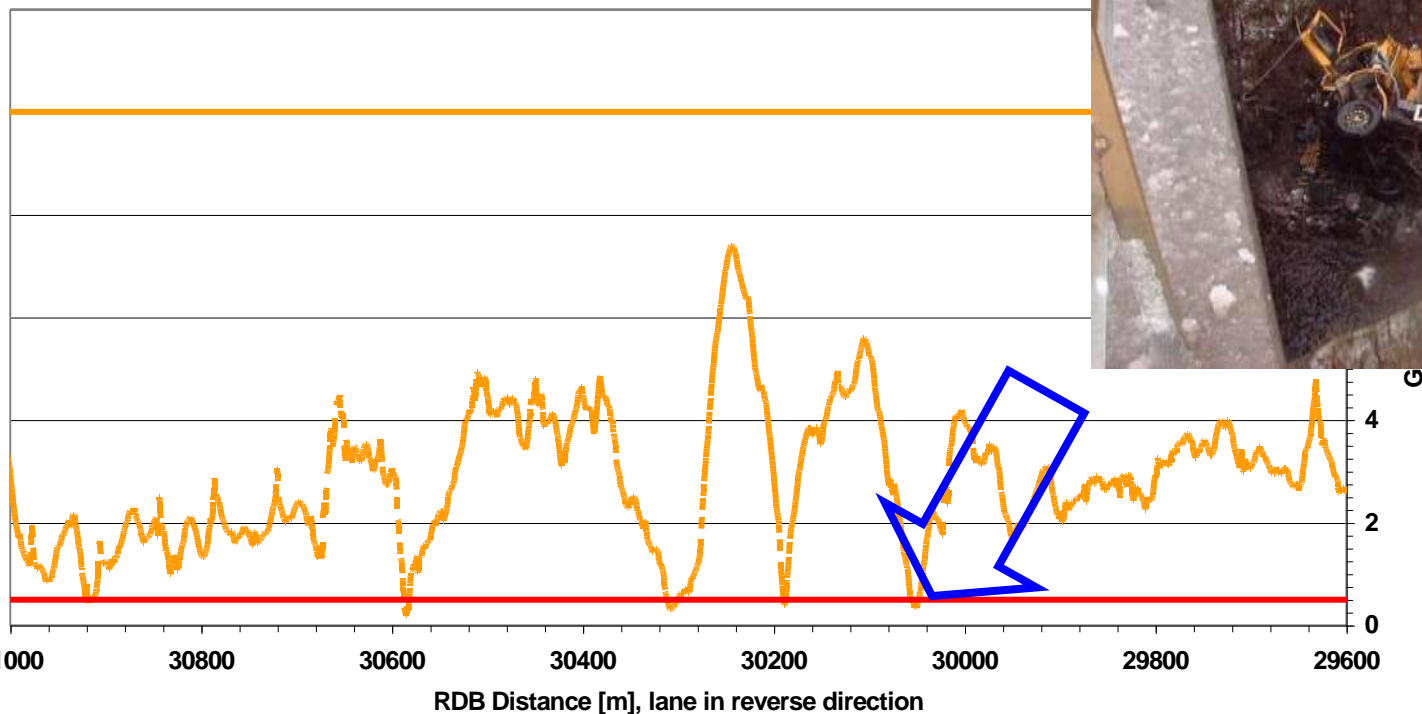
Hazardous Site Viksjö S

Bridge in Viksjö at 30 050 and 30 021 m



Photo: High Coast Rescue Dept

Exit from left hand curve.



-- Drainage Gradient

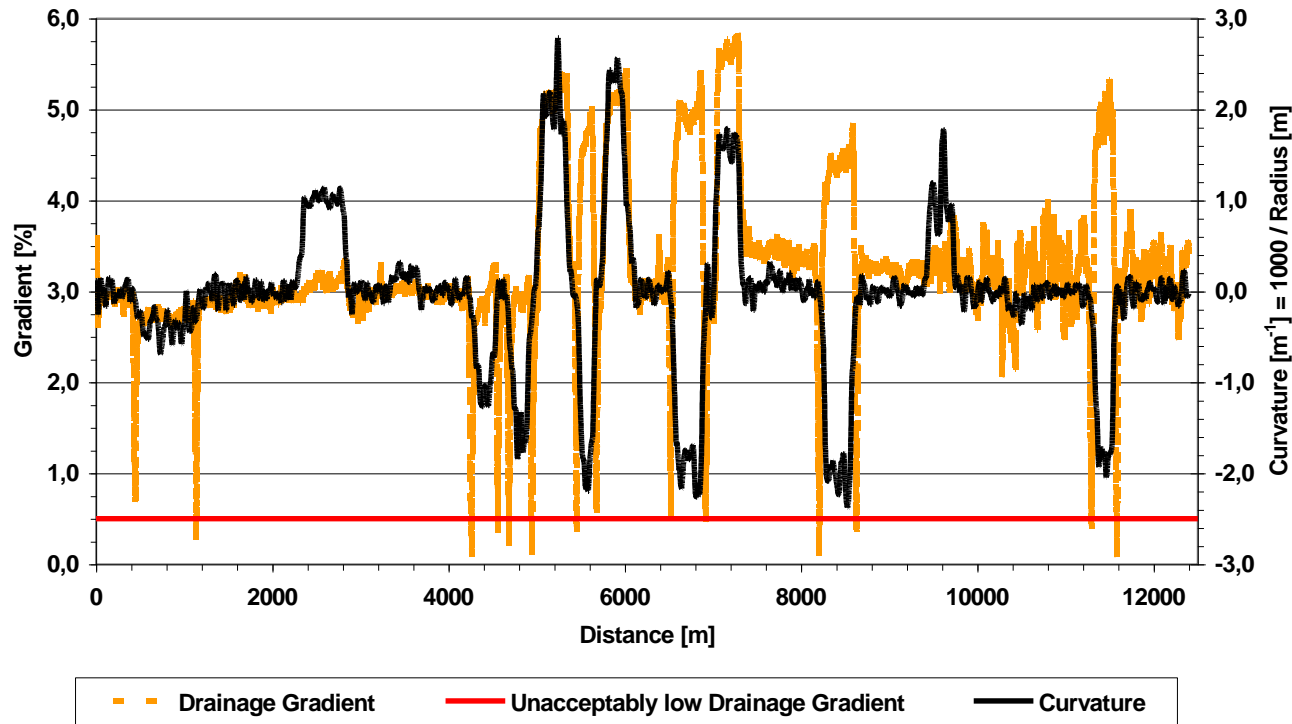
— Unacceptably low Drainage Gradient

— Unacceptably high Gradient



Also new highways can include hazards

New Hw 90: **12 Hazardous Sites** within 12.3 km.



All HS are at entrance or exits of **left hand curves**.



Conclusions on ride vibration



**Daily vibration exposure A(8) exceeded EU Action Value.
Bumps gave high compression stress in the spine.
Timber hauliers like Brorssons Åkeri AB are now
obliged, by law, to make risk assessment and
implement organizational and/or technical actions to
minimize the driver's vibration exposure.
These actions will bring significant costs to hauliers and
their customers in the forest industry, et c.**



Conclusion on lateral buffeting



High transient lateral forces at Hazardous Sites.

Road sections with high truck roll/lateral vibration are found with the new RBCSV parameter.

On heavy truck routes such as the Beaver Road 331, the pavement shoulders needs to be widened and strengthened.



Conclusions, cont'd



High RBCS variance at Hazardous Sites.

Safety issues also related to Cross Slope vs Curvature.

- And to Drainage Gradient lower than 0.5 %.

Entrances and exits of left hand curves are hot spots.



Easy to identify HS with high B/C ratio for repair action.



Conclusions, cont'd



Road administrators must quickly identify Hazardous Sites (HS), warn road users, and ASAP make relevant repair [*Tylösand Declaration*].

The Roadex III Project have demonstrated methods to identify HS with high Rut Bottom Cross Slope variance, "erroneously banked curves" as well as low Drainage Gradients.

Consultants and Contractors should face extremely high penalties, if their work results in too low Drainage Gradients. (Focus on left hand curve transitions).





Want to know more?



Visit the project website www.roadex.org

Search for the 140 page report "*Health Issues Raised By Poorly Maintained Road Networks*".



Comfort, comfort my people,
says your God.



A voice of one calling in the desert;

-Prepare the way for the Lord, make straight paths for him. Every valley shall be filled in, every mountain and hill made low. The crooked roads shall become straight, the rough ways smooth.

***The path of the righteous is level;
O upright One, you make the way of the righteous smooth. And all mankind will see God's salvation.***



Isaiah 26:7, Isaiah 40:1,3-5, Luke 3:5