

“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



Photo: Niklas Thunborg.

***Last Monday, 20<sup>th</sup> 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			
	NRA Northern Region			
	The Highland Council, Forest Enterprise, The Western Isles Council	 The Highland Council The Highland Council The Highland Council	 Forest Enterprise	



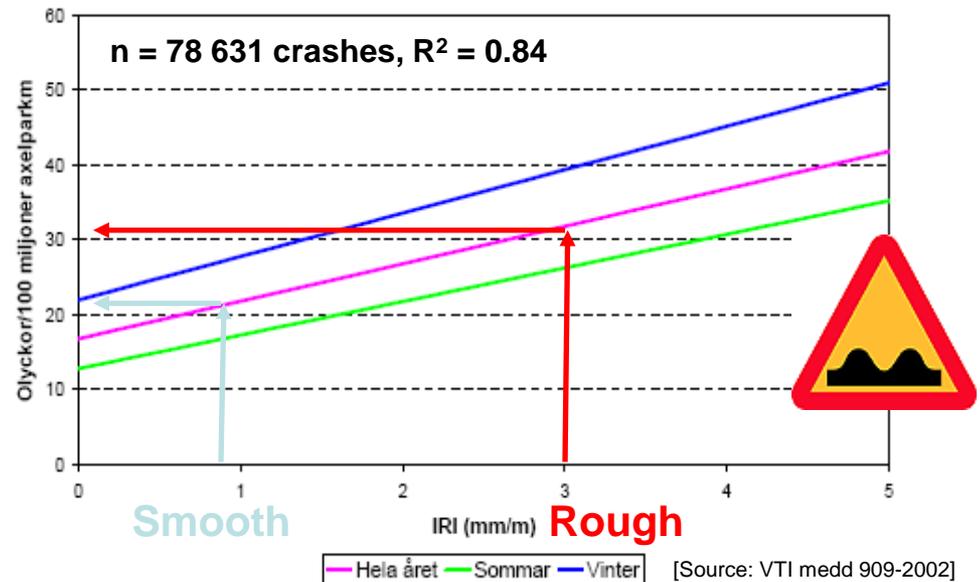
# Disproportionate health and safety risks



**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.**





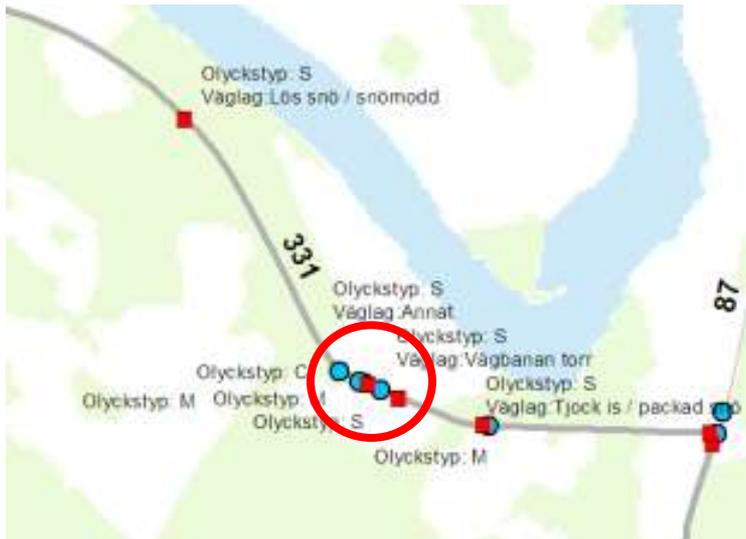
# Accident locations

## -Clustered, not randomized



### The Viksjö Haz. Sites

### The Roos Curve Haz. Site





# 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.**

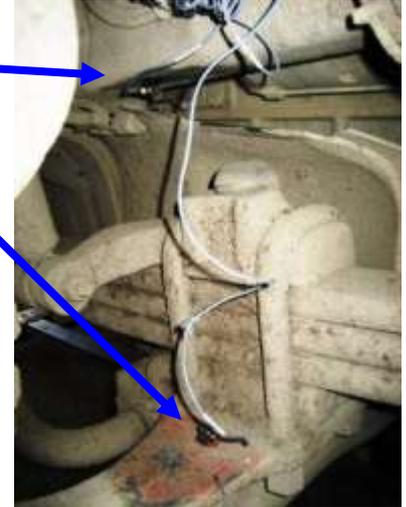
**Z-axis at L and R front wheel axles.**

**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

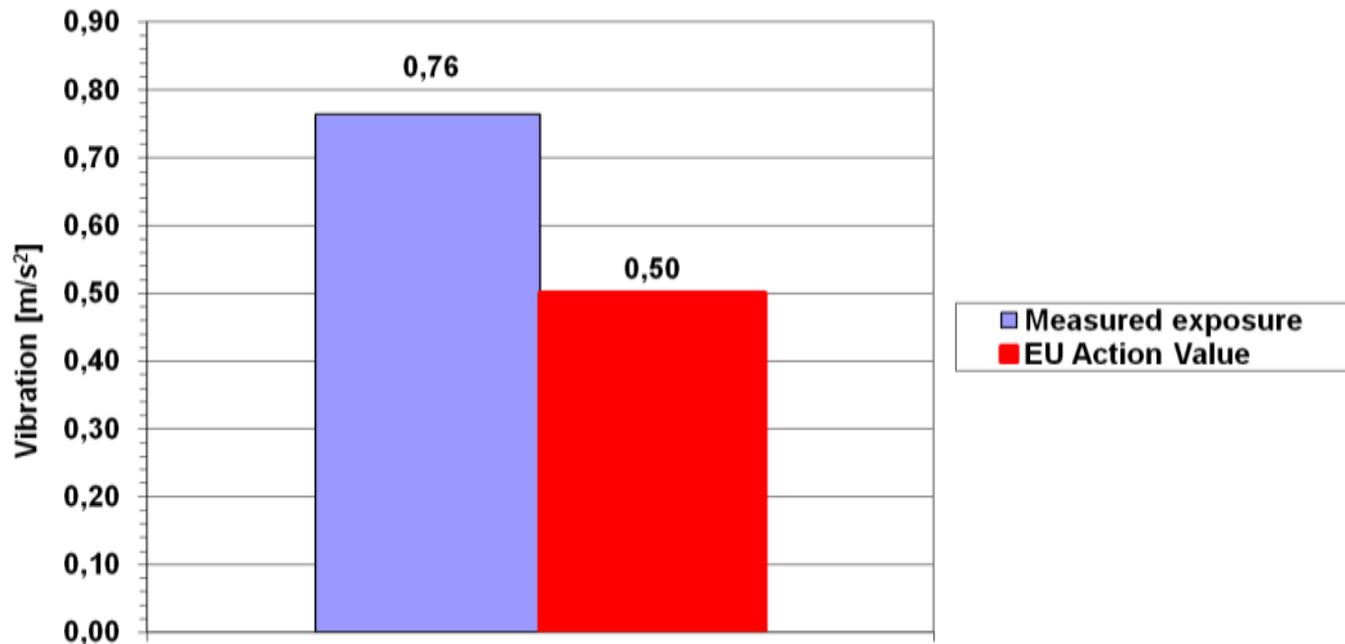


# Results: 1. Daily vibration exposure A(8)

Results for normal driving shifts:

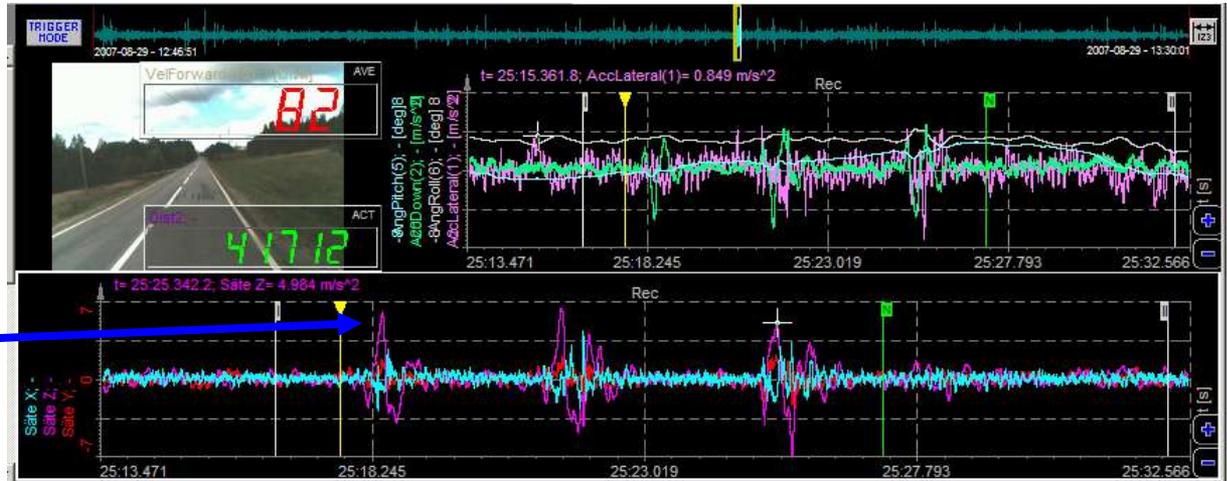
$$A(8) = 0.76 \text{ m/s}^2.$$

Exceeding the EU Action Value 0.5 m/s<sup>2</sup>.





## 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.**

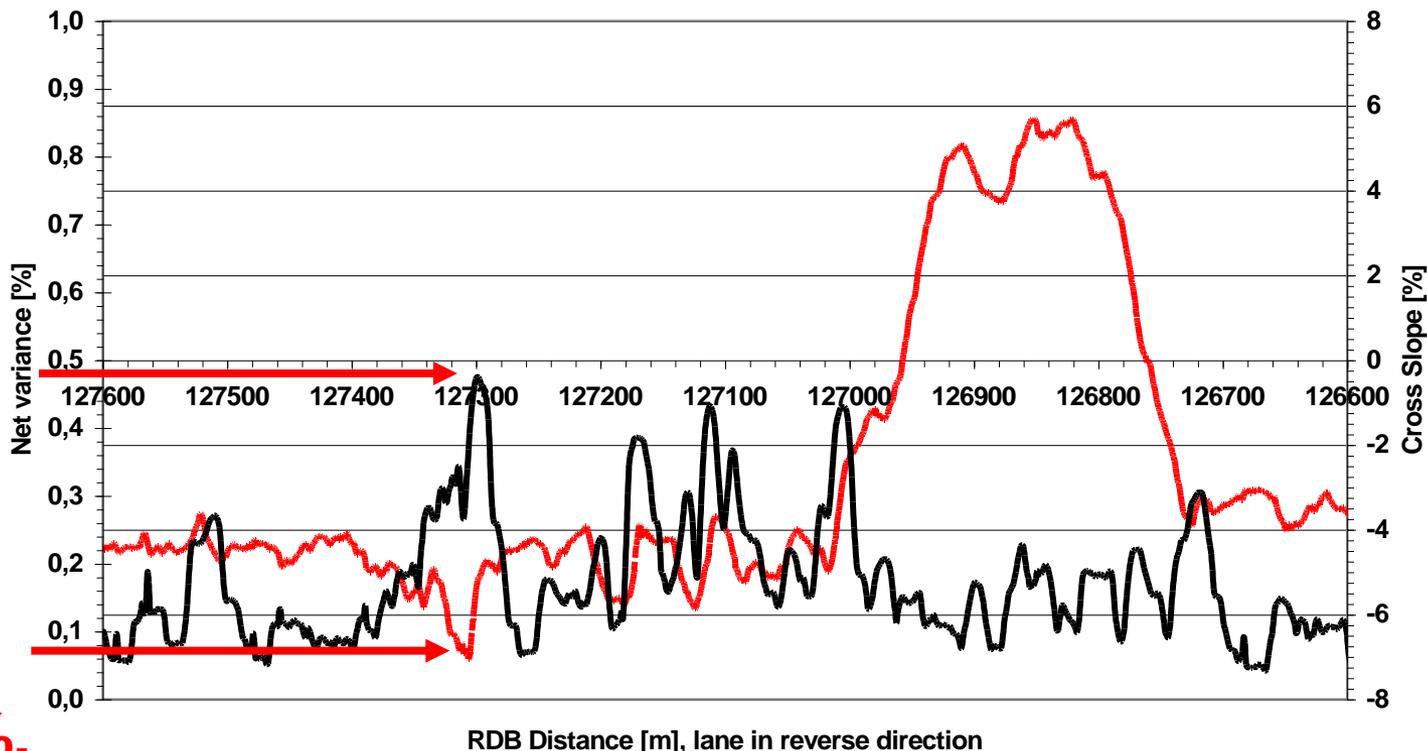


**In-truck data:  
3,5°/s change in cab  
roll angle**





# High RBCS variance at HS Backe



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



# Rock n' Roll at HS Åkerö

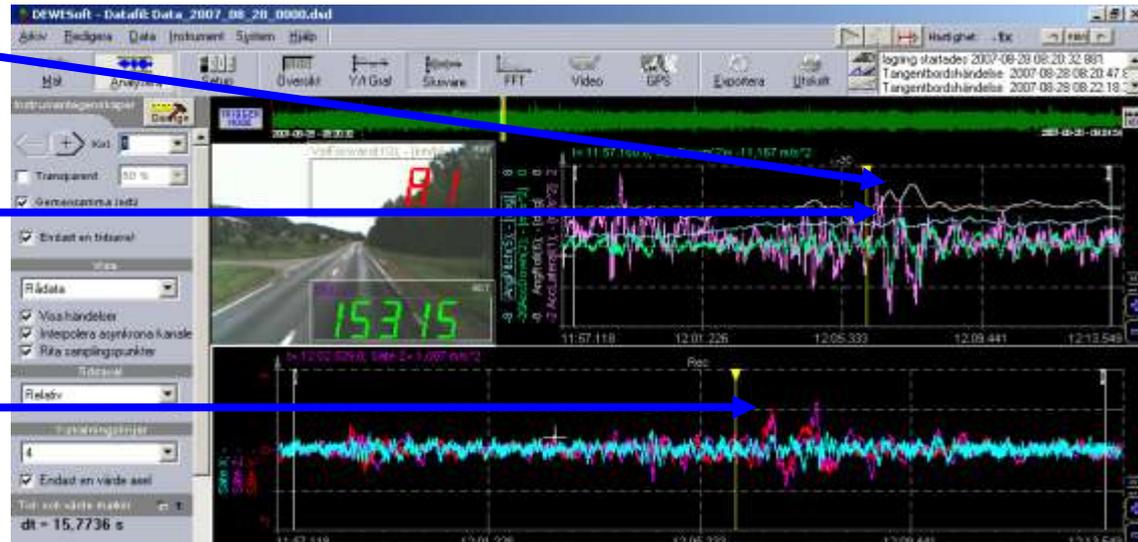
**Straight road.**

**Truck cab roll angle:**

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

**High lateral acc in  
cab: 2 m/s<sup>2</sup>.**

**Very high lateral acc at  
driver seat : 3.5  
m/s<sup>2</sup>. (+ 75 %)**





# High RBCS variance at HS Åkerö

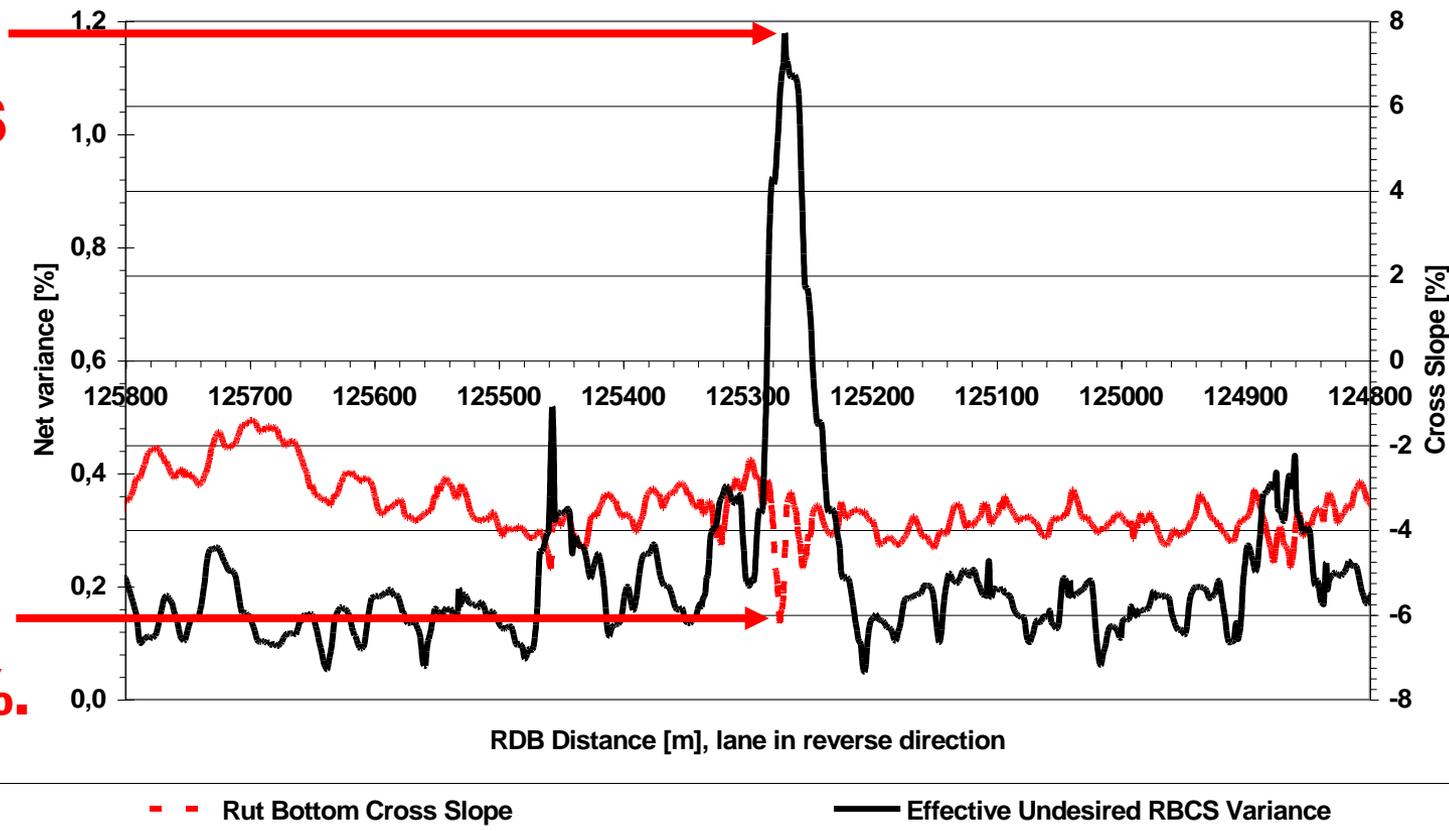


**Straight road.**

**Alarm!**

**1.18 % RBCS  
variance.**

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



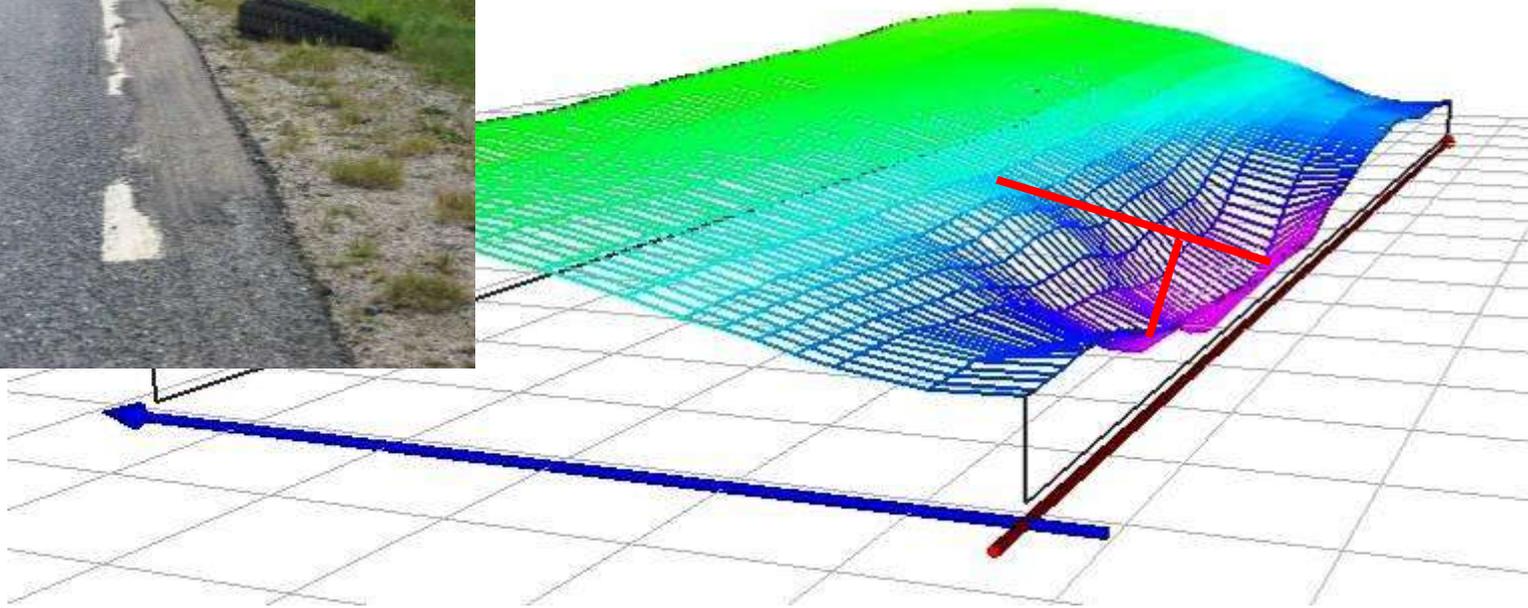


# 3D laserscan at HS Åkerö

**Note: Exploded truck tire**



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



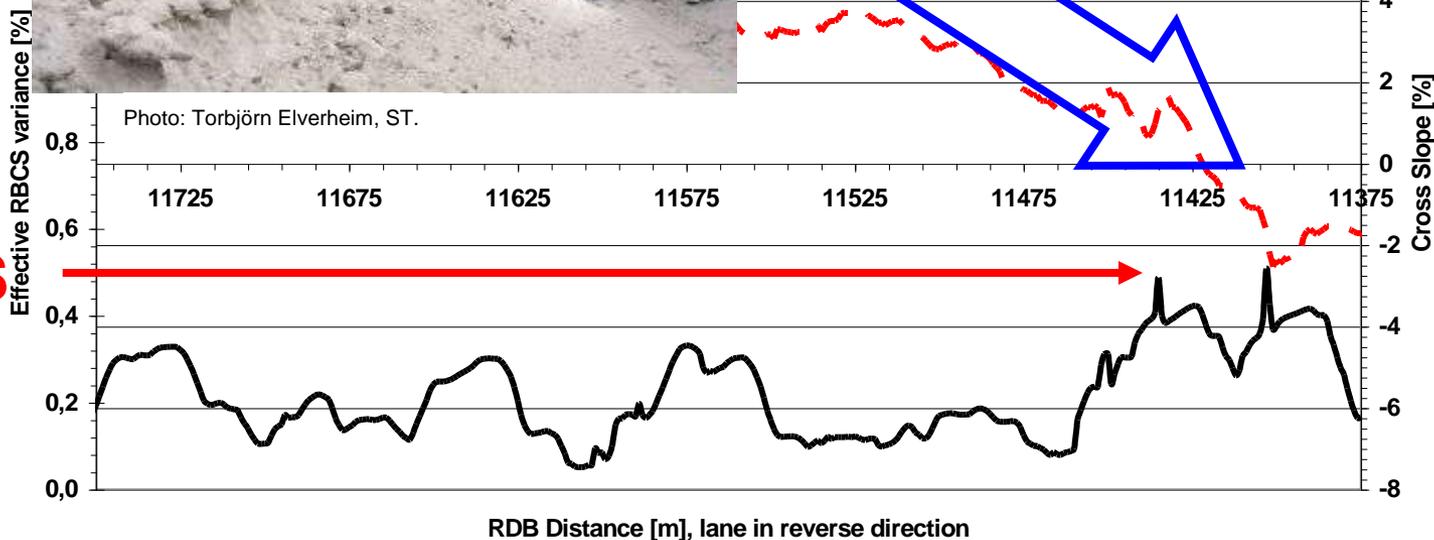


# RBCS at HS Åsäng

**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

Photo: Torbjörn Elverheim, ST.

**Alarm!**  
**0.49 % RBCS**  
**variance.**



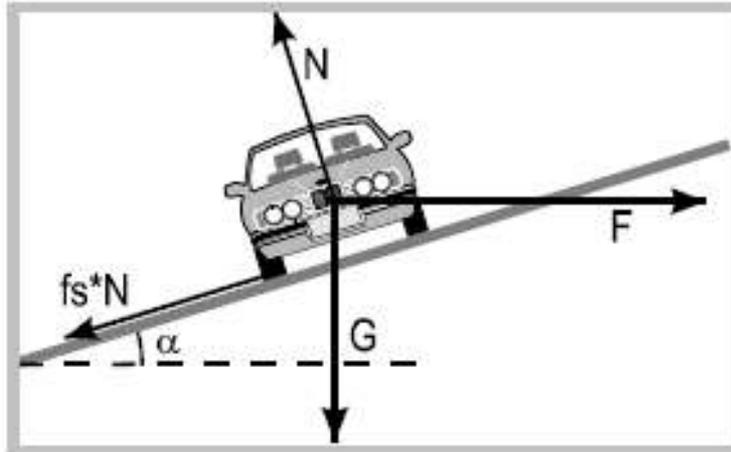
## Safety issues also related to:

- 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)

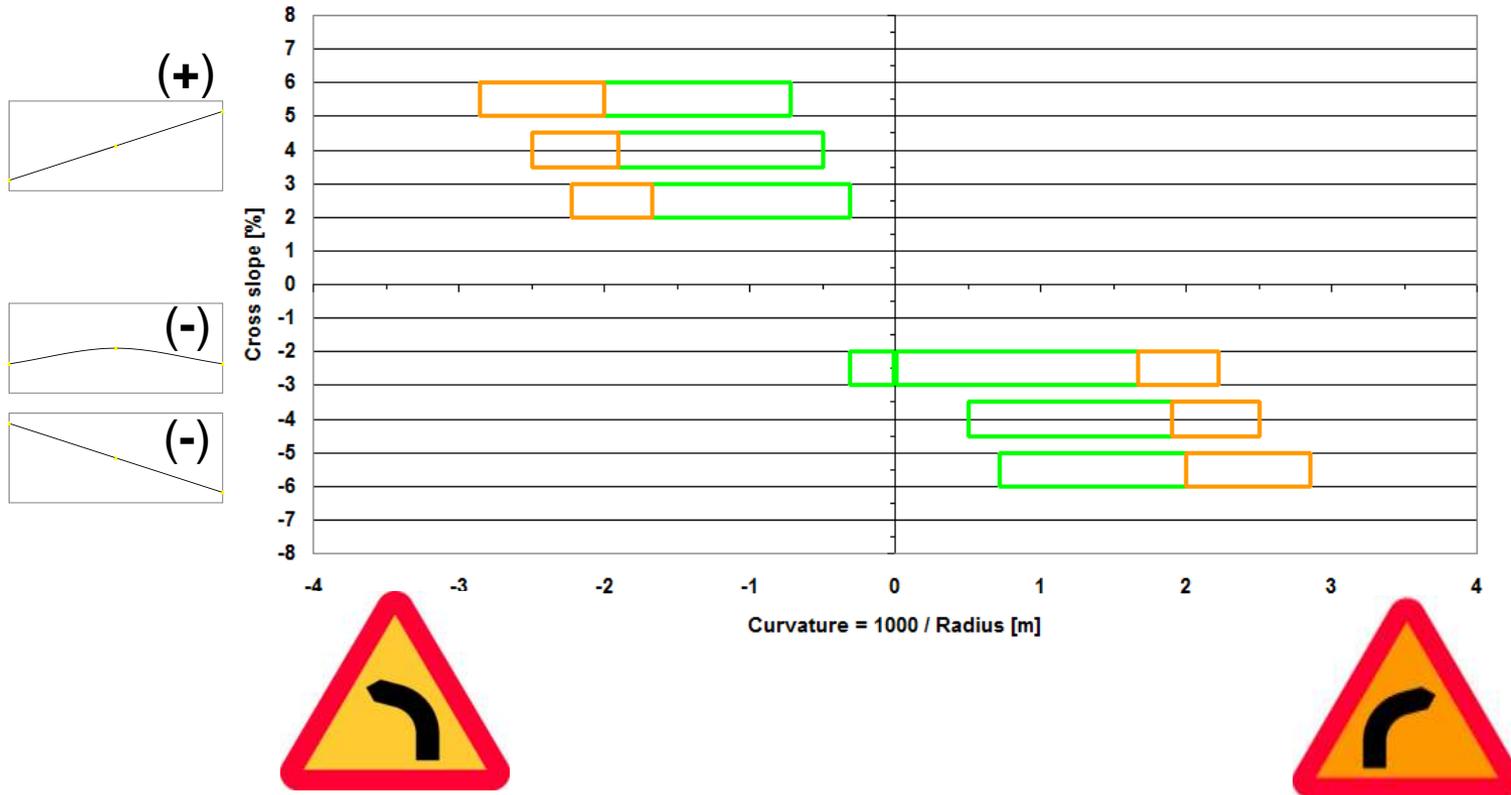


# Ideal ratios for Cross Slope vs Curvature

Swedish Design Guidelines for 90 km/h.

Green box = High standard.

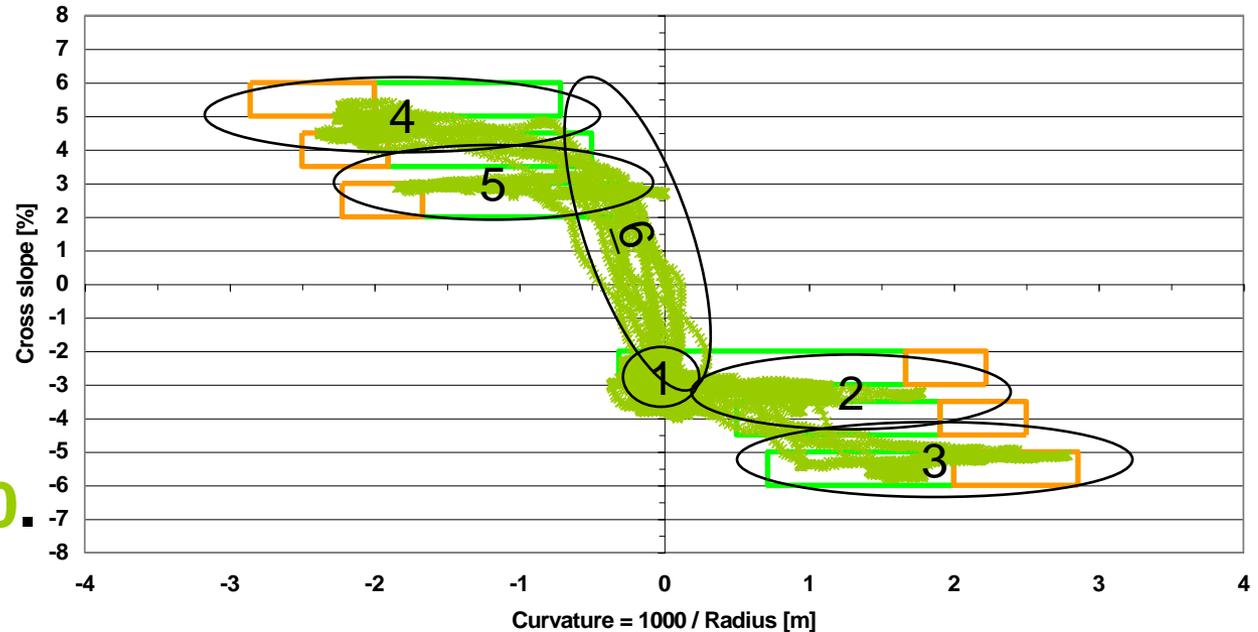
Orange box = Moderate to Low standard.





# 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

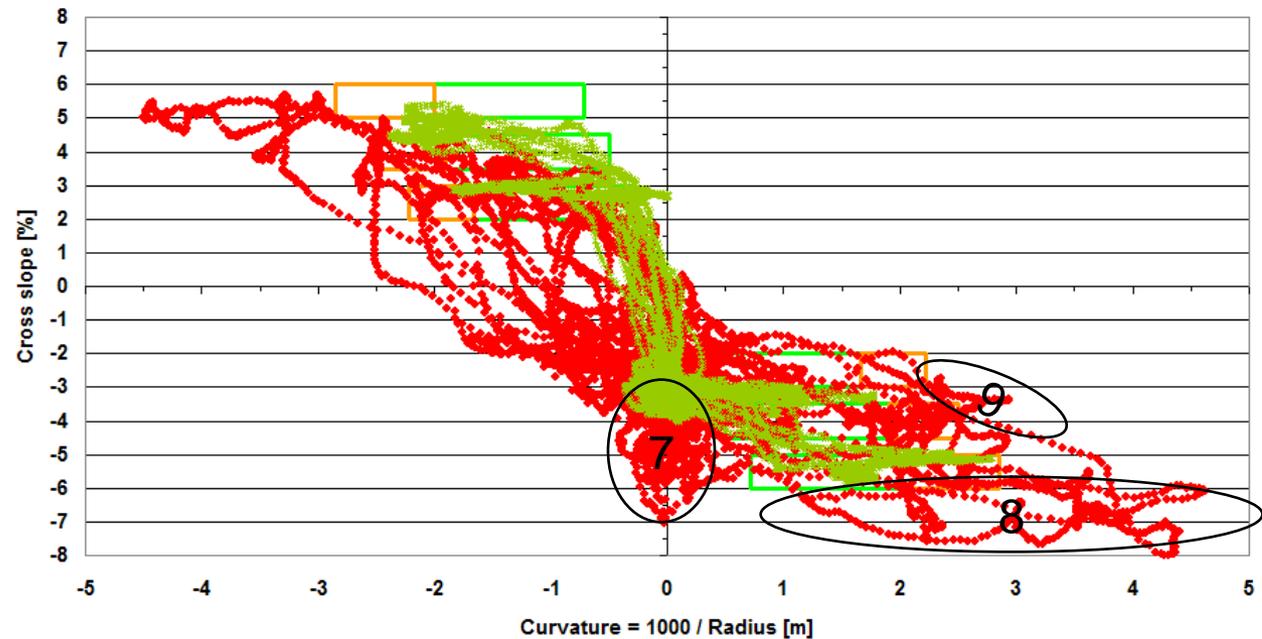
5: Wide left hand curves

6: Transitions at left hand curves



# Rd 331: Improperly banked curves

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



## Straight sections:

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

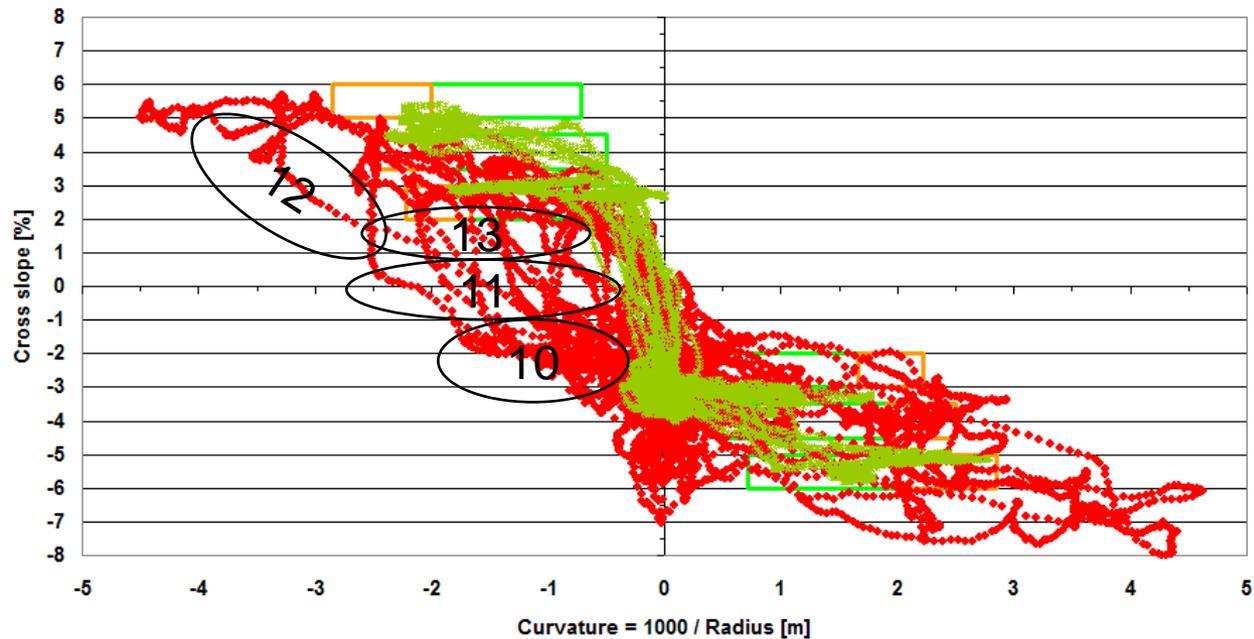
## Right hand curves:

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!

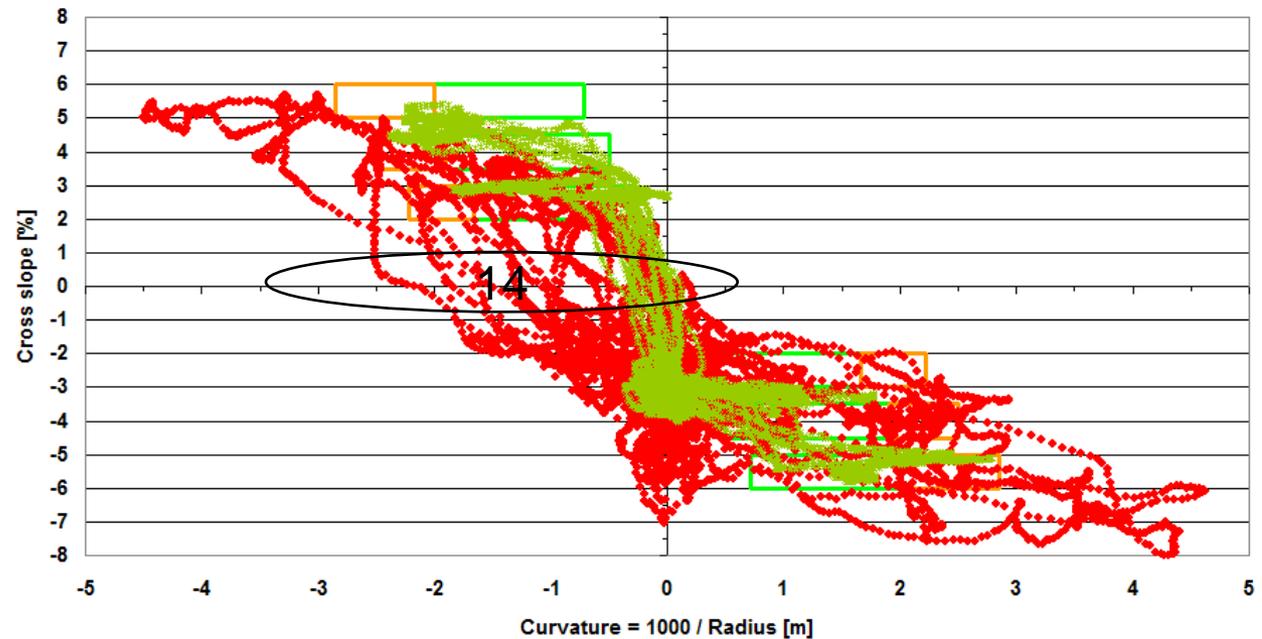
12: Too little Cross Slope – skid risk!

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*

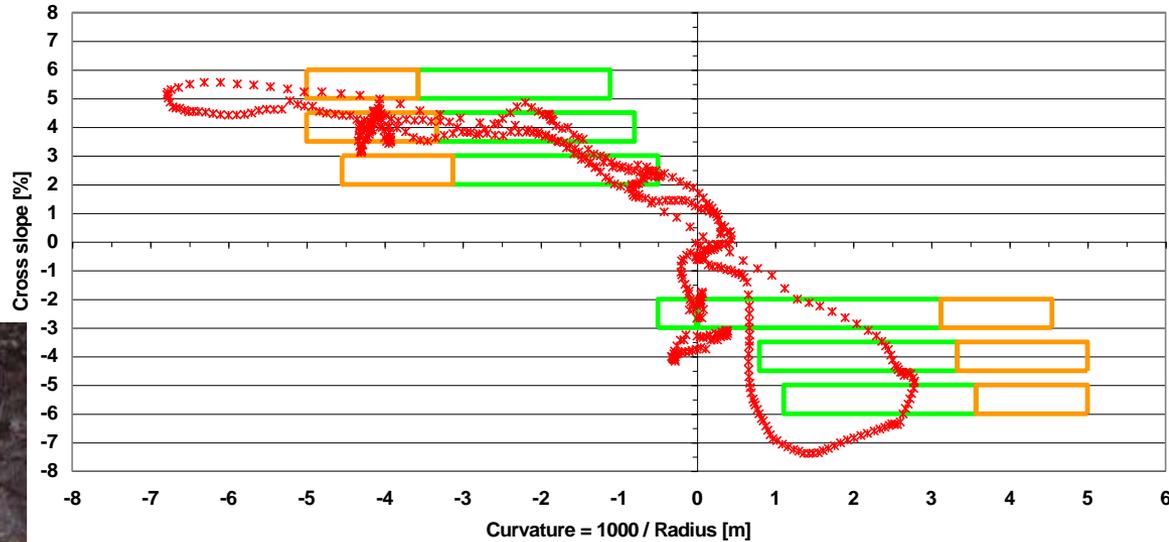
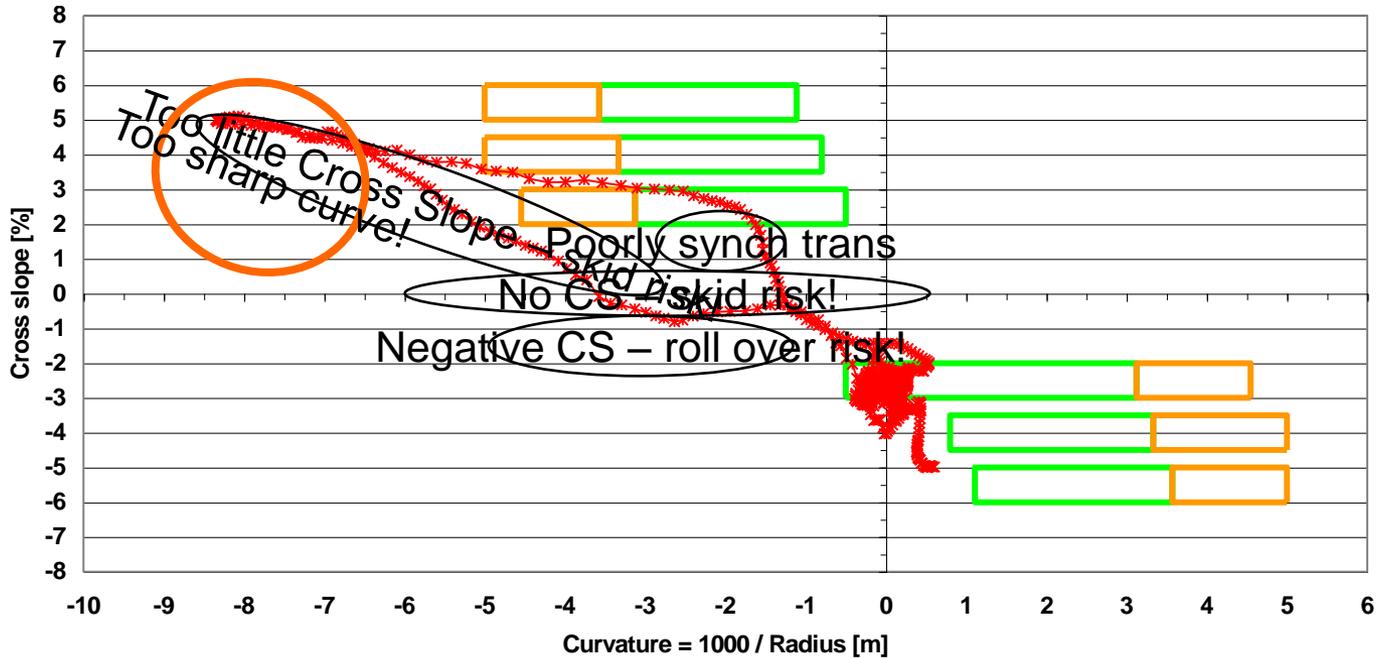


Photo: High Coast Rescue  
Dept





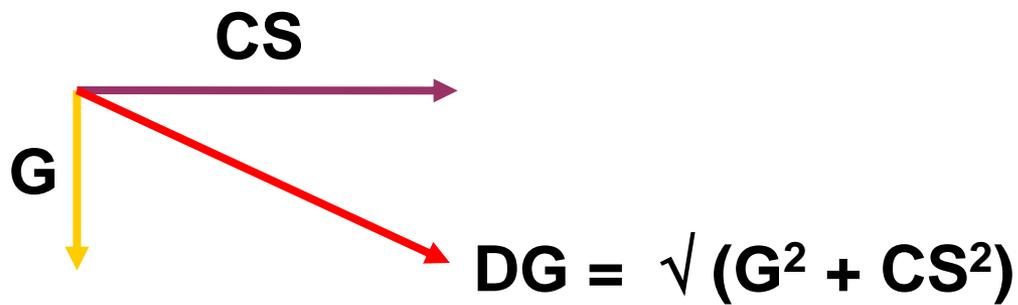
# Hazardous Site Roos Curve





# 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.****



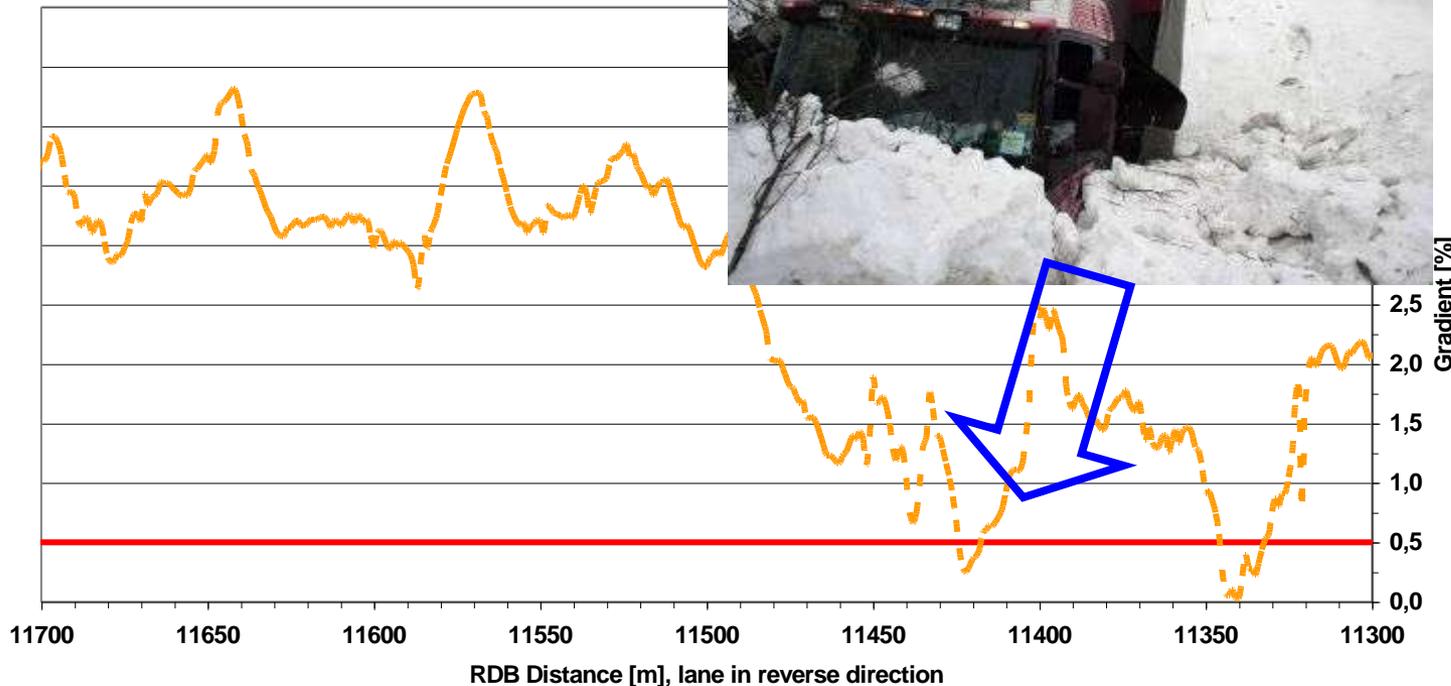
# Hazardous Site Åsäng

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.

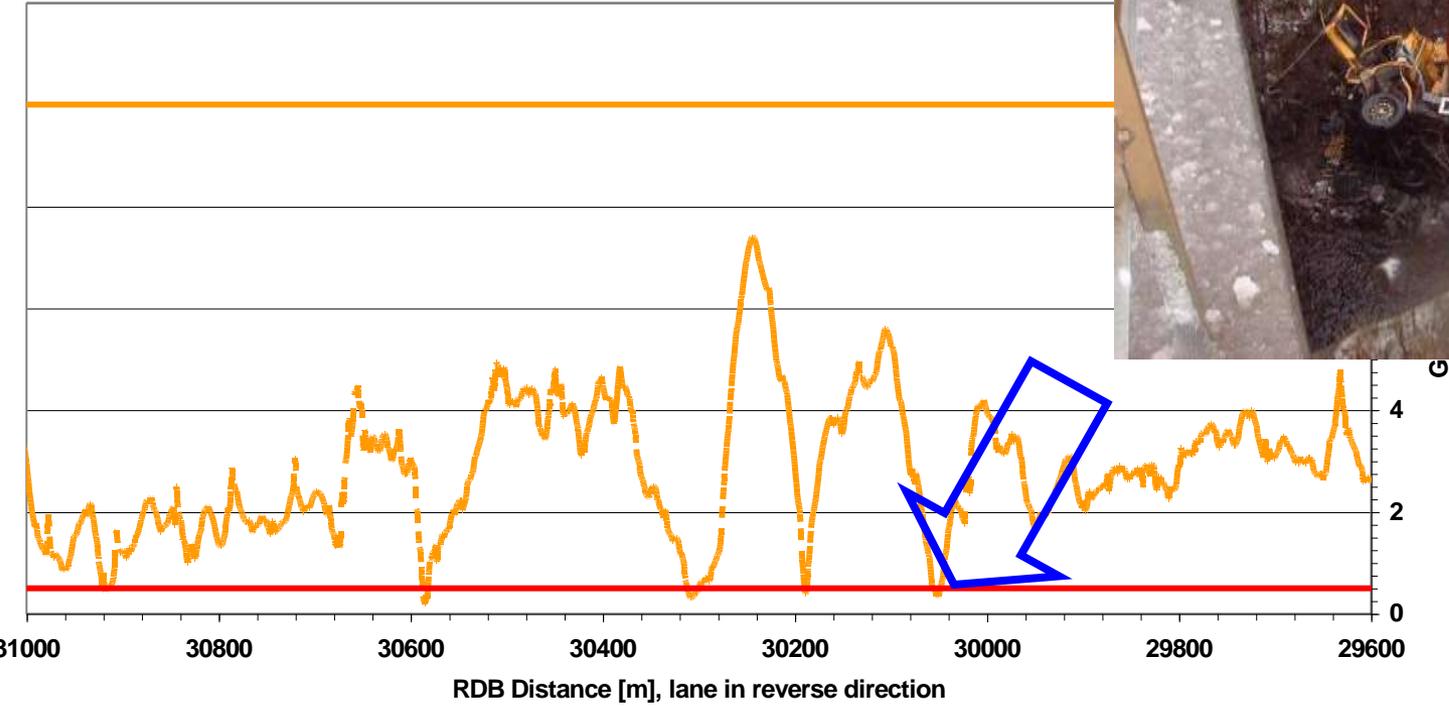


# Hazardous Site Viksjö S

Bridge in Viksjö at 30 050 and 30 021 m



Photo: High Coast Rescue Dept



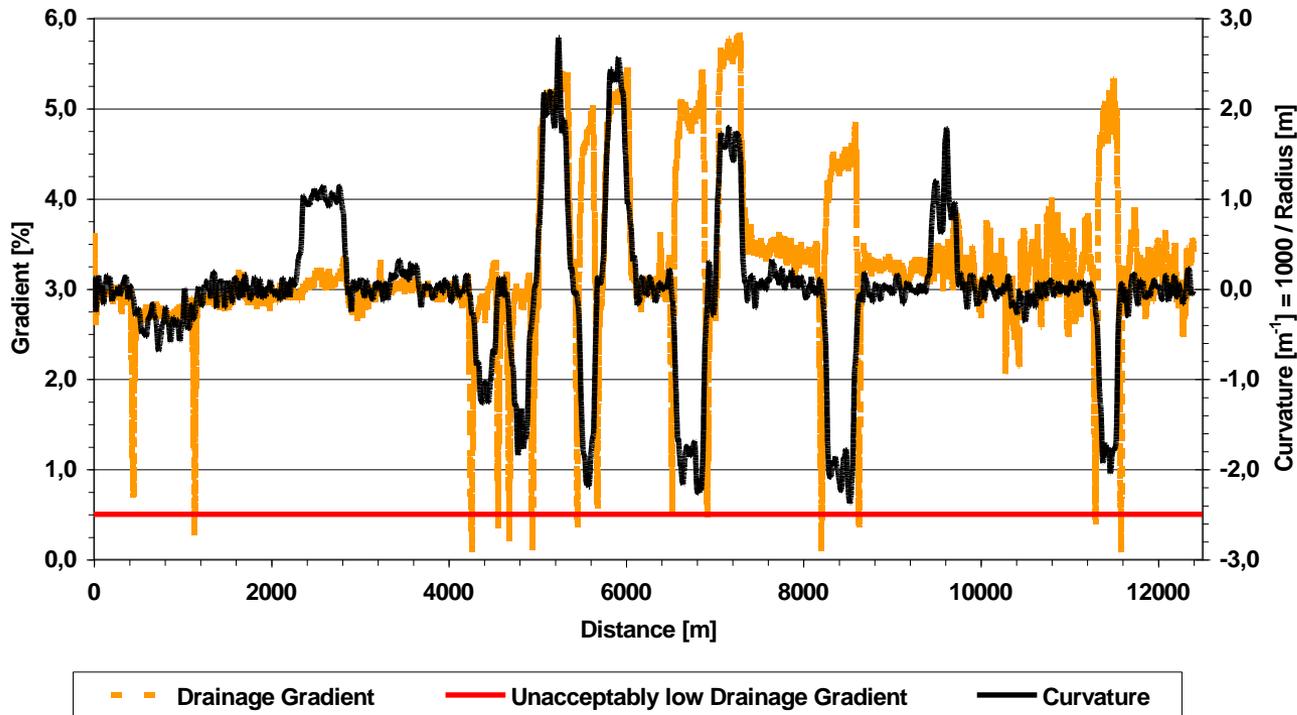
**Exit from left hand curve.**





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](http://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