Design approach regarding critical train speed according to the Swedish technical requirements

need for clarification and changes

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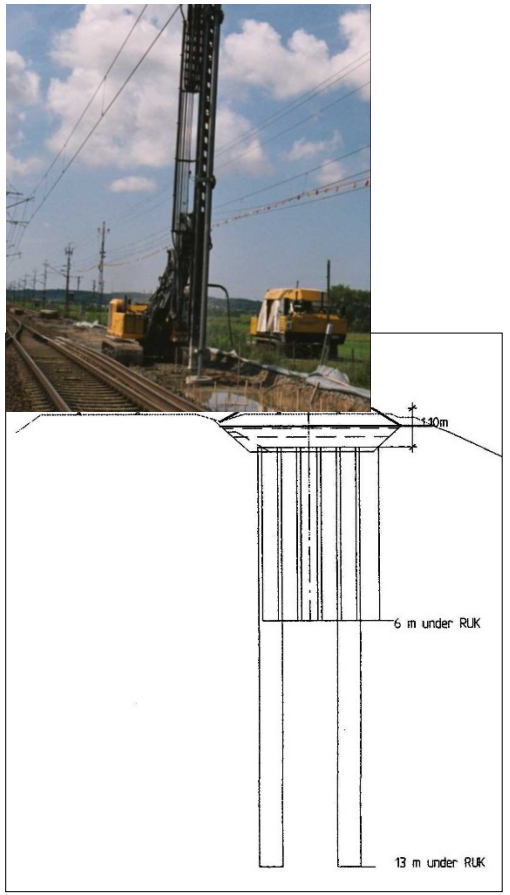
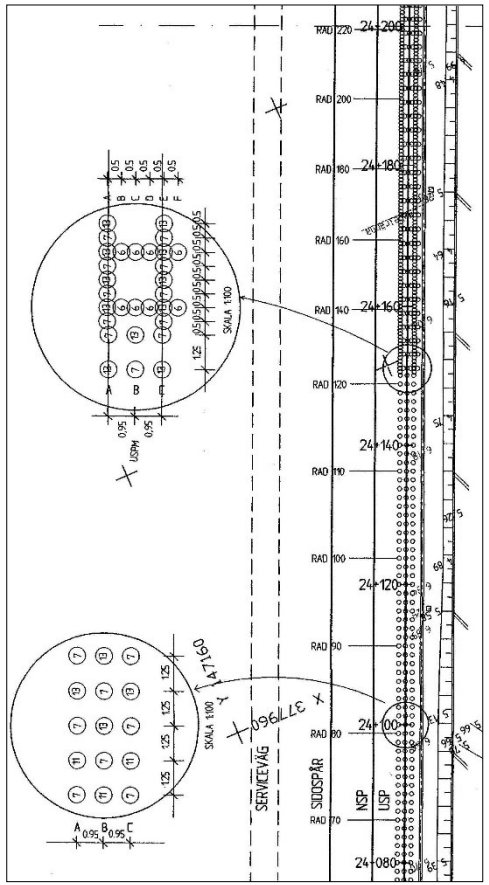
Background

The "High Speed Phenomenon" was observed in Sweden for the first time in 1997 on the Västkustbanan, parts of the section Mölndal-Kungsbacka, in connection with an increase in the maximum speed of the trains to 200 km/h.
Ledsgård, about 5 km north of Kungsbacka was one of these sites.
(Bo Andréasson et al, tidskriften Bygg & teknik nr 1/02)

Background

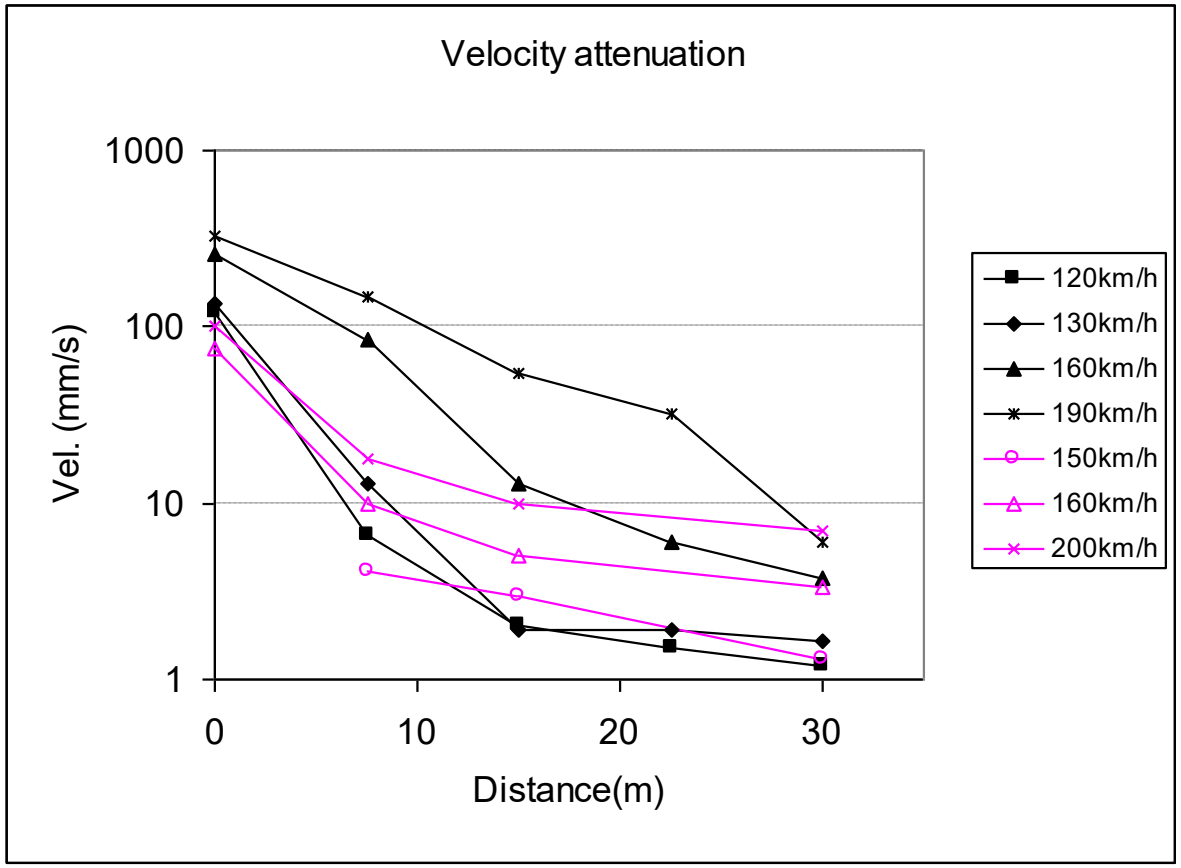
- The problem at Ledsgård was solved by means of a specially designed lime-cement column reinforcement of the soil under the railway embankment.
  The Countermeasure was performed only for the new track (USP).
  (Bo Andréasson et al, tidskriften Bygg & teknik nr 1/02)





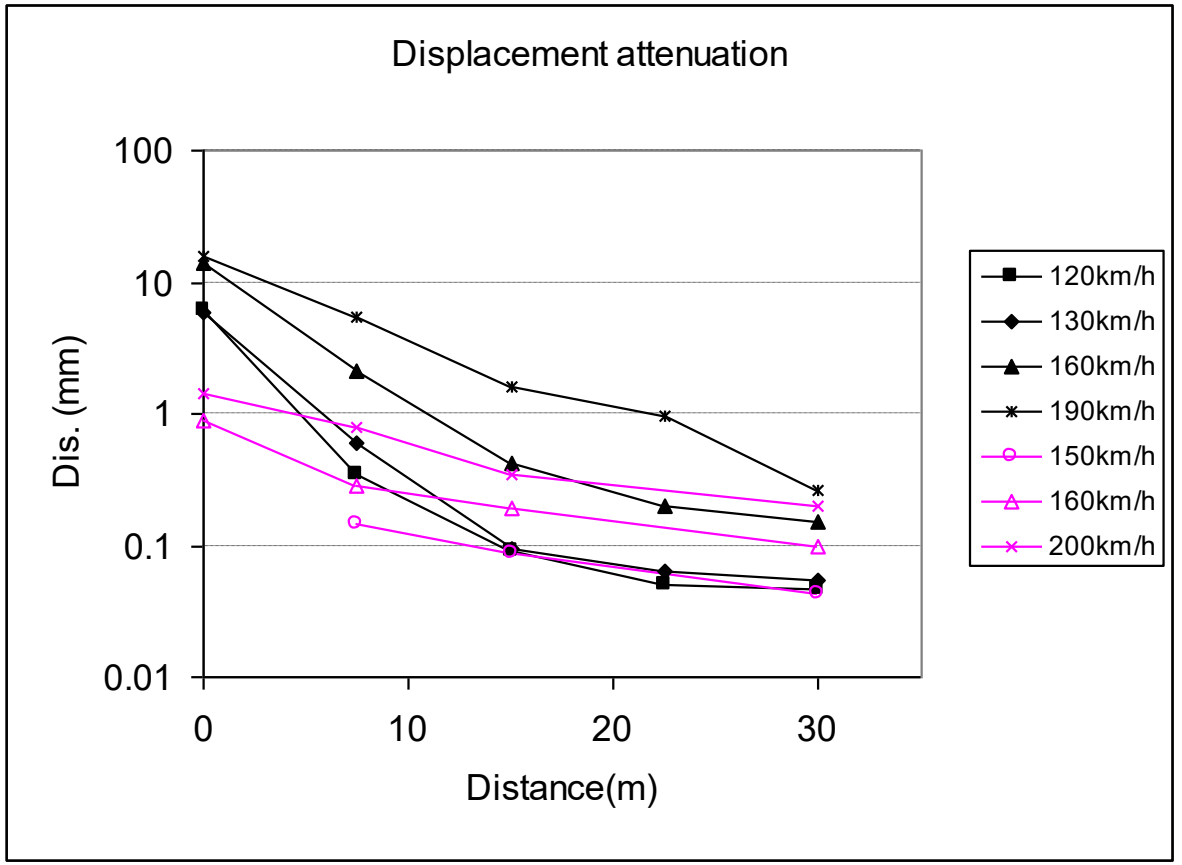
Background

- Comparison between measurement results before (black line) and after (pink line) LC-columns showed a substantial reduction of vibration amplitude in the track.



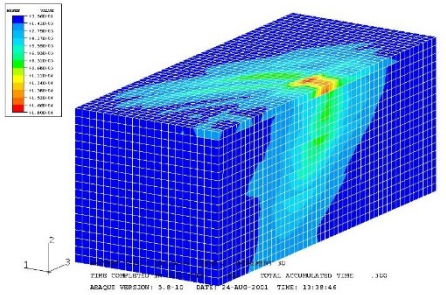
Background

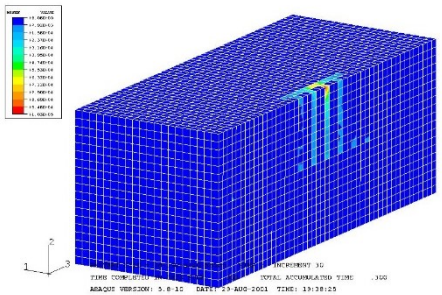
- Comparison between top-top displacement before (black line) and after (pink line) LC-columns also showed a substantial reduction of vibration amplitude in the track.
- Reduction of the vibration amplitude was most effective in the track and its vicinity, specially for the displacement curves.

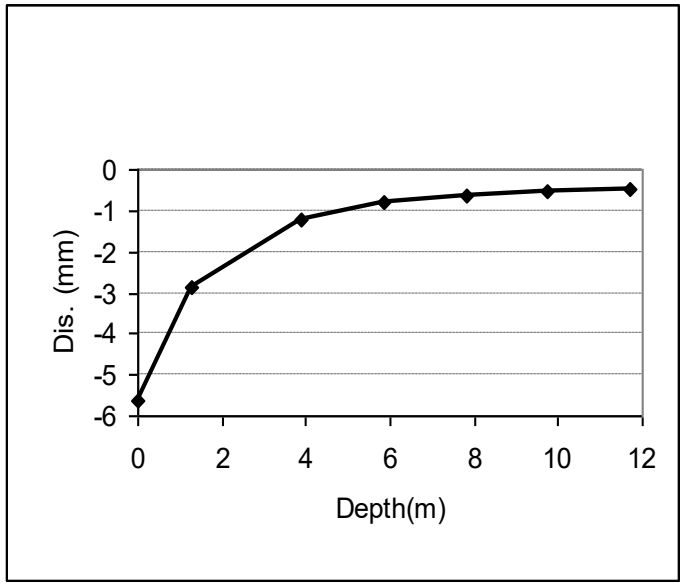


Background

- Simulation of train passages before and after countermeasure using LC-columns showed that for the Ledsgård site there is an optimum depth of the columns at about 5m.



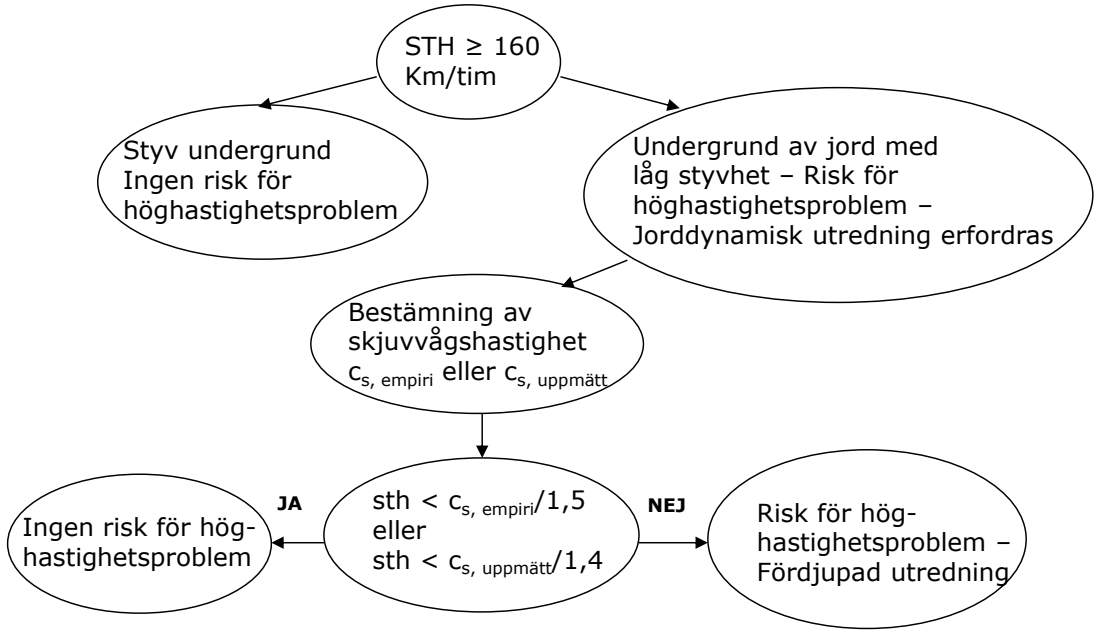




TK Geo 13

Initial assessment, chapter 18.1:

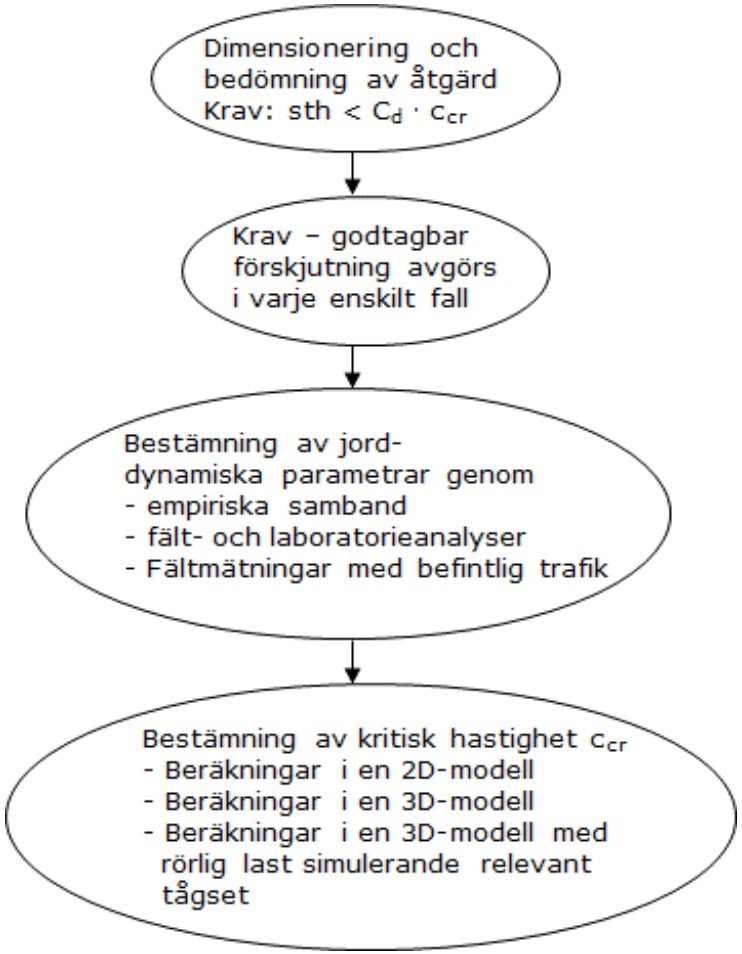
- The check is necessary if STH (highest train speed of the track) is higher than 160 km/h.
- Compare the shear wave velocity with STH multiplied by 1.4 (if c_s is measure) or 1.5 (if c_s is estimated).
- If cs is not satisfactory continue with detailed assessment according to chapter 18.3.



TK Geo 13

Detailed assessment, chapter 18.3:

1. Determine requirement with respect to displacement at bottom edge of sleeper.
2. Determine dynamic soil properties.
3. Determine the critical speed.
4. Check the requirement STH<C_d*c_{cr} (choose factor C_d according to Table 18.3-1, 18.3-2 and 18.3-3).
5. Check the requirement with respect to allowable displacement.
6. Repeat step 3-5 until both requirements are fulfilled.



TK Geo 13

Detailed assessment, chapter 18.3:

- Factor C_d is determined using Table 18.3-3 depending on accuracy of the soil parameters (Table 18.3-1) and accuracy of the calculated critical speed, c_{cr} (Table 18.3-2).
- If maximum displacement at bottom edge of sleeper is less than 2 mm it is allowed to use a higher C_d than that given by Table 18.3-3 after consultation with Trafikverket.

DokumentID	Ärendenummer	Version
TDOK 2013:0667	TRV 2014/13914	2.0

Tabell 18.3-1. Utredningsnivåer för bestämning av jorddynamiska parametrar.

Utredningsnivå	Bestämning av jorddynamiska parametrar (skjuvvågshastighet c_s, initiell skjuvmodul G_0, skjuvmodul G)
A1	Jorddynamiska parametrar bestäms utgående från konventionella geotekniska undersökningar och empiriska samband enligt avsnitt 5.2.2.5.3.
A2	Skjuvvågshastigheten i undergrunden bestäms genom mätningar in situ. I övrigt enligt A1.
A3	Skjuvvågshastigheten i undergrunden bestäms genom mätningar in situ och skjuvmodulens deformationsberoende bestäms i laboratorium.

Tabell 18.3-2. Utredningsnivåer för bestämning av kritisk hastighet.

Utredningsnivå	Bestämning av kritisk hastighet
B1	Kritisk hastighet bestäms utgående från etablerade parametrar genom beräkning av vågutbredningshastigheten i en 2D-modell.
B2	Kritisk hastighet bestäms utgående från etablerade parametrar genom beräkning av vågutbredningshastigheten i en 3D-modell.
B3	Kritisk hastighet bestäms utgående från etablerade parametrar genom beräkning av vågutbredningshastigheten i en 3D-modell samt med rörlig last simulerande relevanta tågset.

Tabell 18.3-3. C_d enligt avsnitt 3.6.1.

Utredningsnivå	A1	A2	A3
B1	0,50	0,55	0,60
B2	0,55	0,60	0,65
B3	0,60	0,65	0,70

TK Geo 13

- Pattern av LC-columns in plan is regulated by Table 13.2-1.
- The only acceptable patterns, when LC-columns are used for vibration mitigation, are lattice or block.
- No limitation is given with respect to depth of the LC-columns.

Tabell 13.2-1. Pelarmönster vid olika dimensioneringssituationer.

Dimensioneringssituation	Acceptabla pelarmönster			
	singulära	skivor	gitter	block
Stabilisering under bankar i aktivzonen där $F_{c,ostab} \geq 0,67$	X	X	X	X
Stabilisering under bankar i aktivzonen där $F_{c,ostab} < 0,67$[1]		X	X	X
Stabilisering i passivzon och direkt skjuvzon		X	X	X
Skärningsslänter $F_{komb,\ ostab} > 0,60$		X	X	X
Pelare vilka installeras mot kraftigt lutande fast botten, (> 45°), där $F_{ostab} < 1,0$		X	X	X
Stabilisering av järnvägsbankar där s.k. höghastighetsfenomen kan uppkomma			X	X

Some experiences

- When LC-columns are used, determining of the critical speed is not a straightforward task.
- When maximum displacement is small, it seems not relevant any more to determine the critical speed.
- Using other patterns than lattice could be as effective.

Conclusions

- It seems that vibration related requirements in TK Geo is based on experiences from sites like Ledsgård.
- While determining the critical speed is usually straightforward in case of unstabilized soil, it could be difficult to identify a critical speed when LC-columns are installed.
- It is a relevant question why both the requirement with respect to displacement as well as critical speed must be fulfilled, specially when the maximum displacement at sleeper bottom edge is small.
- It seems that other patterns than lattice and block could be as effective while LC-columns are used as vibration mitigation method.
- Table 13.2-1 needs to be completed with requirement with respect to minimum depth of LC-columns if lattice pattern is a necessity.

Suggestions

- The design code should present a maximum allowable displacement based on train safety and track maintenance.
- Fulfillment of requirement with respect to either critical speed or maximum displacement as defined above should be enough.
- Instead of accepting only certain patterns of LC-columns the requirement should be related to the function of the columns. This may open the way for using other patterns.
- If lattice pattern in Table 13.2-1is kept as a requirement it should be completed with requirement regarding the minimum depth of the columns in each direction.

Thank you

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