Routine measurement of long wavelength irregularities from vehicle-based equipment

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RailMeasurement

scope of presentation

- “long-wave” irregularities
  - significant for ground-borne noise and vibration
- how, if at all, are they measured at present?
- what is proposed here with regard to measurement?
- some measurements
- an explanation of what we see
  - reprofiling
  - trackforms
  - other delights
- control of irregularities
  - suggestions
- conclusions

long wave irregularities

- Crossrail specification

(IP D10: ref IWRN12 paper by Rick Methold et al)

'2.10 The nominated undertaker will put in place measures that will ensure that at no point during the operational life of the Crossrail passenger service will the combined power spectral density of the wheel and rail roughness amplitudes be worse than 30 dB re 1 micron on the 1/3 octave centred on a wavelength of 2m, decreasing by 15 dB per tenfold reduction in wavelength.'

NB This is a combined wheel/rail roughness. However, it is shown in this paper that typical ***wheel*** roughness << IP D10 limit for λ>0.5m i.e. rail roughness controls whether spec is met at longer wavelengths.

  - For trains at 100km/h, wavelength range of interest is 0.1-1.4m (20-280Hz).

- Nelson and Watry (IWRN11 re Sound Transit)
  - 3.16-100Hz (significantly lower frequency range)

measurement requirements and conclusions regarding instrumentation

- straight-edge based equipment cannot measure the longer wavelengths of interest (>1m)
- to reduce statistical uncertainty, long runs must be measured
- therefore equipment is required with which a continuous measurement can be obtained
- inertial-based system is in principle the best way of measuring acoustic roughness
  - CAT (Corrugation Analysis Trolley) has been used for some Crossrail work, with measurements taken at higher speed and with longer integration constant to improve long wave response
  - It has also been shown (IWRN11) that RCA (Rail Corrugation Analyser) obtains "acoustic-quality" measurements for 10-5000mm.

NB Both types of equipment were originally developed for quality assurance of rail reprofiling work.

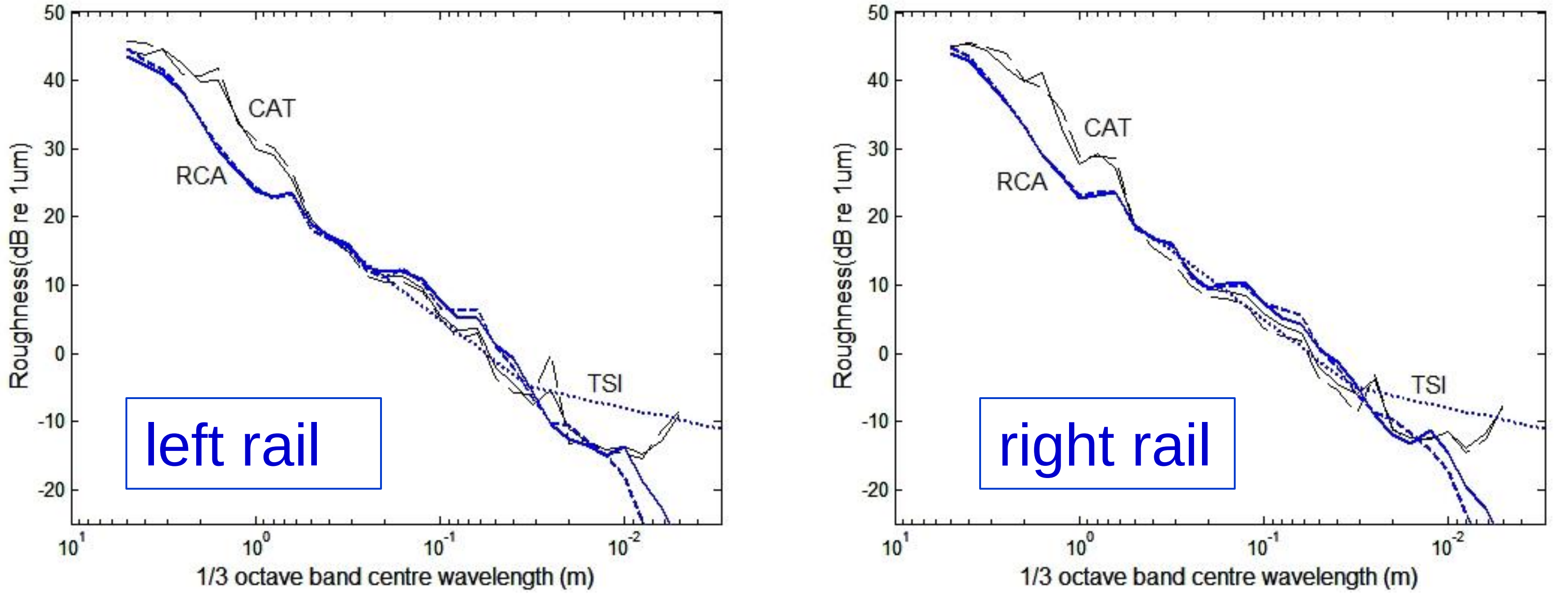
equipment

- CAT
  - portable trolley, carried to site and operated by a single person
  - originally designed (1990s) for 10-3000mm wavelength range
  - widely used now for acoustics

- RCA
  - used primarily for routine QA of reprofiling work
  - originally designed also for 10-3000mm wavelength range

NB Most reprofiling trains do not use this equipment.

equivalence of CAT and grinder-based RCA (6-5000mm)



- IWRN11 paper
  - Excellent correlation of CAT and RCA for 10 < λ < 700mm
  - RCA gives lower estimate for shorter and longer wavelengths
  - evidence that RCA is more repeatable at longer wavelengths (>1m)

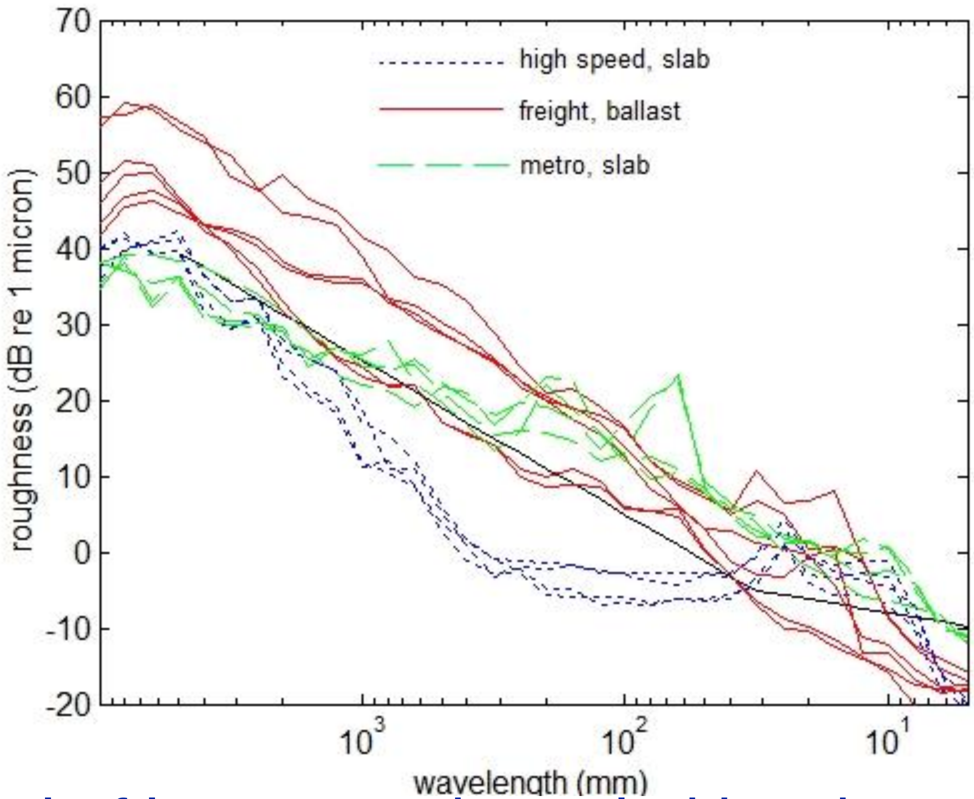
NB CAT was used at “standard” 1m/s c.f. 2m/s used in Crossrail work (interest at time was <u>not</u> long waves!)

What is presented here?

- There are several RCAs in routine use; some have been in routine use for more than a decade.
- Measurements obtained from several railway systems:
  - several metros, one high-speed
  - non-ballasted track (different types), ballast
- What can we see and what can we deduce, particularly with regard to long waves and effects of
  - trackform
  - reprofiling
  - other delights

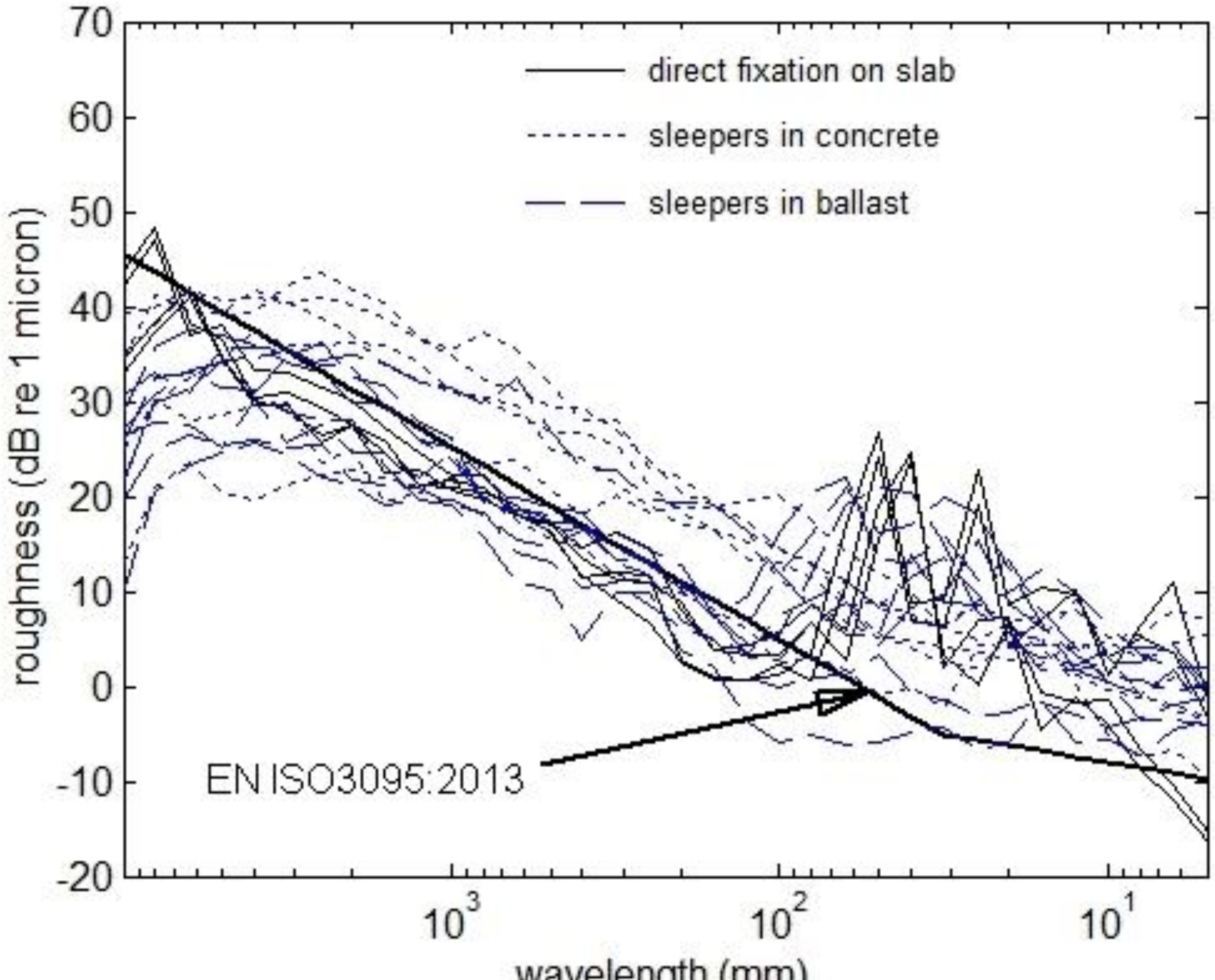
NB Care should be taken with reading too much into the data, as this is a limited sample. However, the measurements are taken from several hundred if not several thousand km of measurements on several systems over a period of a decade.

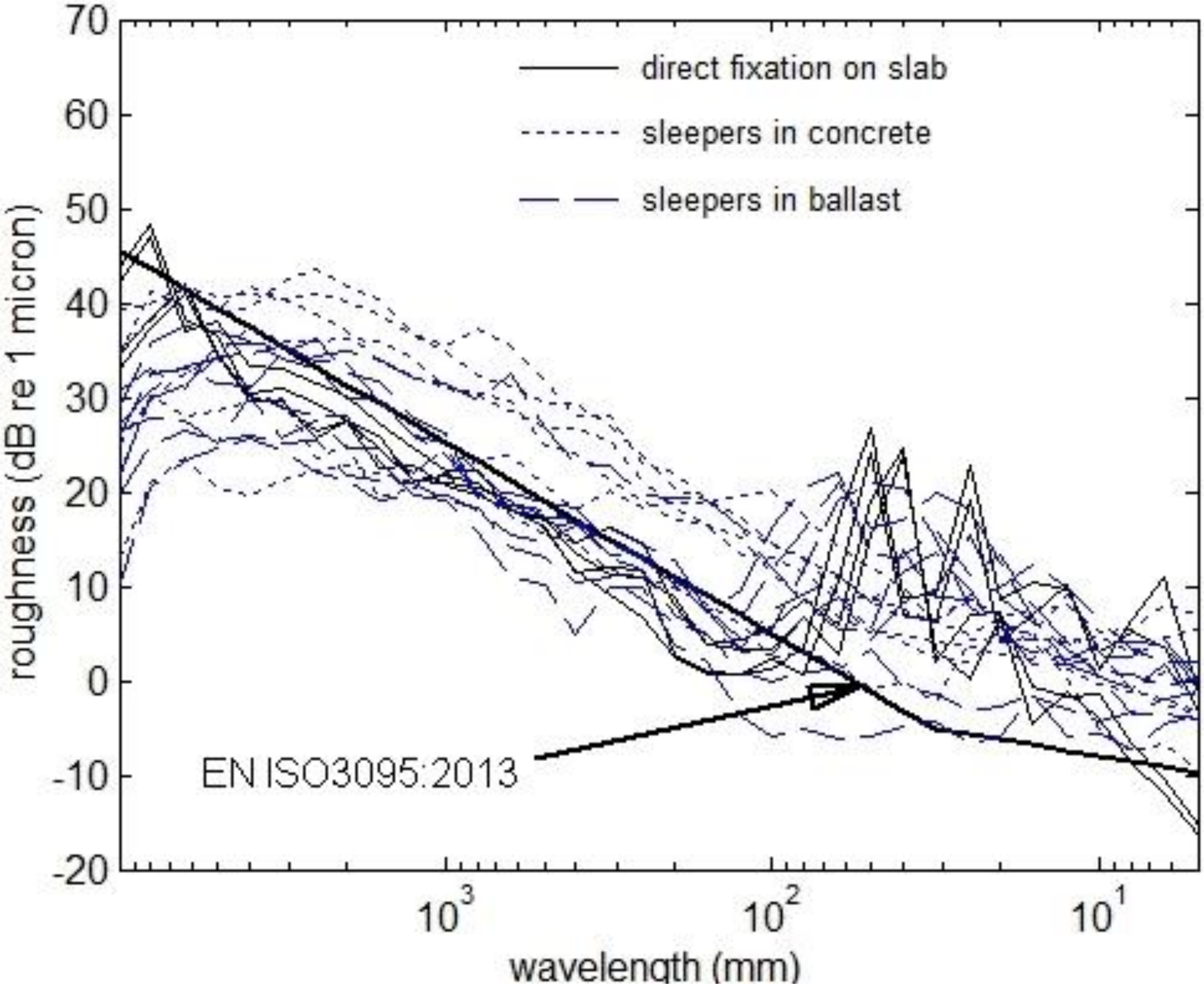
effects of trackform (1)



- slab track has lower level of long wave irregularities than ballast (NB: both slab track systems are relatively new)
- high-speed line has very low level of mid-range irregularities (frequent, routine grinding)
- large variation in irregularities on freight lines
- metro has pronounced corrugation
- grinding signature is evident on all lines

effects of **trackform**:
five metro systems, immediately pre-grind



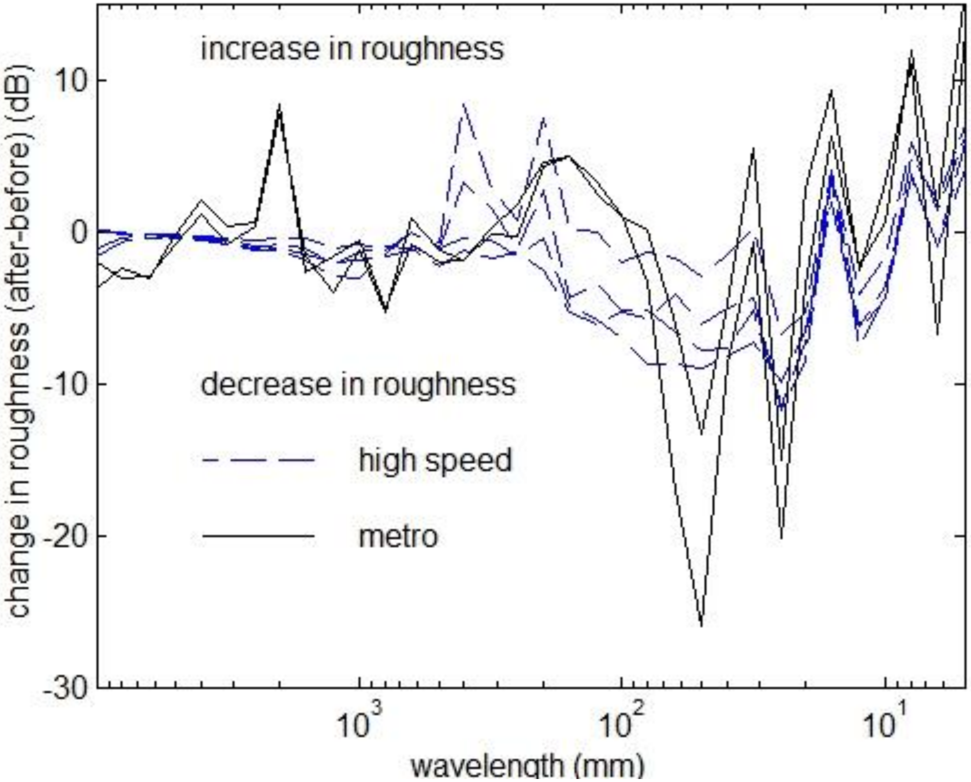


direct fixation on slab
sleepers in concrete
sleepers in ballast
EN ISO3095:2013
roughness (dB re 1 micron)
wavelength (mm)
70
60
50
40
30
20
10
0
-10
-20
10^3
10^2
10^1

effects of trackform: five metro systems, immediately pre-grind

- low level of long wave irregularities on recent system with DF trackform on slab (around ISO3095 line)
- corrugation on <u>all</u> trackforms at 30-80mm
  - but corrugation did not develop at the same rate!
- very little consistency otherwise
  - level of irregularities was probably poorly controlled and monitored during construction (about a century ago up to 20-50 years ago)

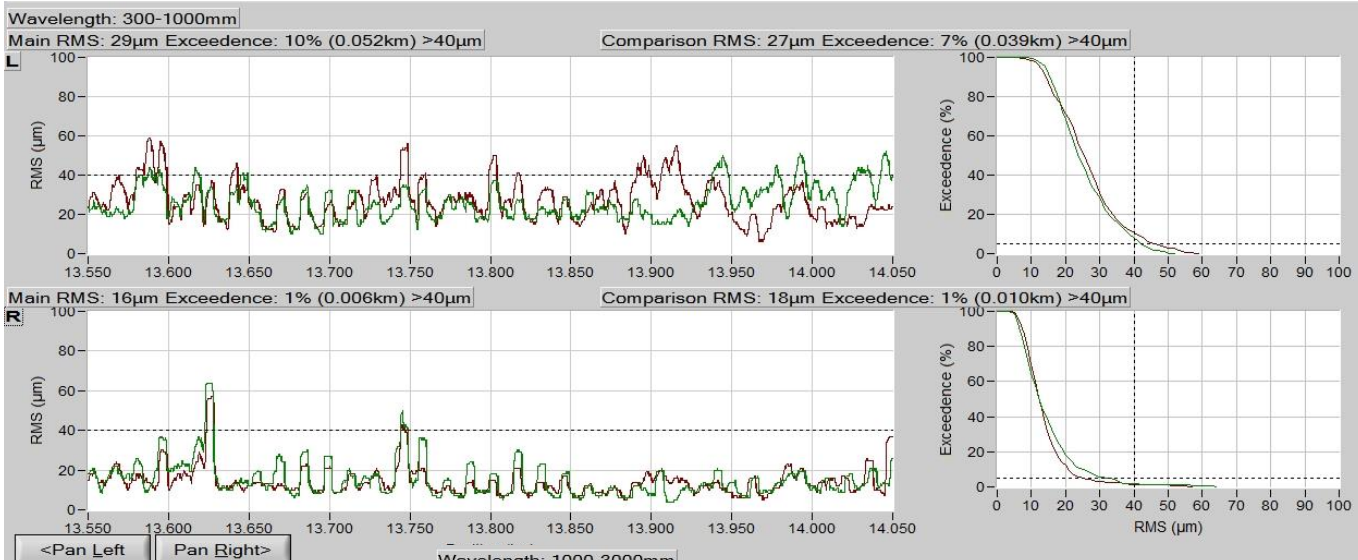
effects of reprofiling: “modern” non-ballasted track systems

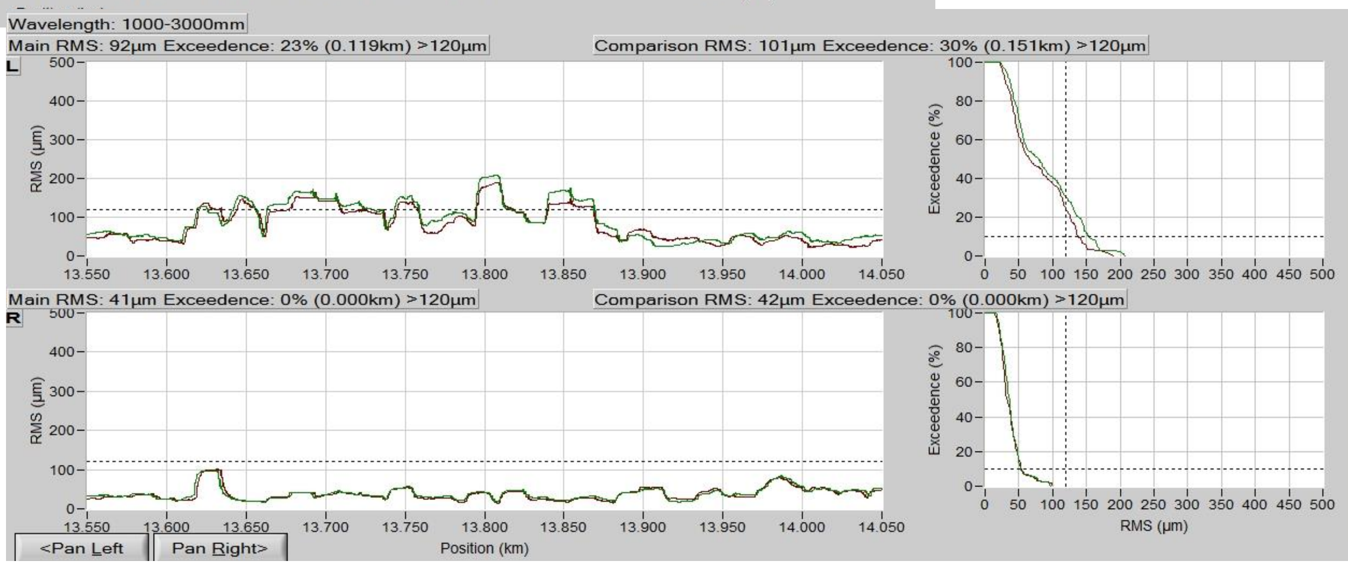


- little effect of reprofiling on irregularities at >1m (except for pronounced effect of “poor set-down” at 2m wavelength)
- for high-speed system, 2-8dB reduction at 30-100mm
- 25dB reduction at 50mm (corrugation wavelength) on metro
- increase of 5-10dB from “grinding signature”

No measurements shown otherwise for metros: not much to add from what is shown in JRRT reference.

other delights





- measurements taken on a metro 22 months apart
  - if a non-ballasted trackform is laid well, the low level of irregularities remains
  - effects of welds and corrugation are mainly at shorter wavelengths (<1m)

control of irregularities

- with present technology, longer wavelengths (>1m) are best controlled by laying slab track, setting out good geometry, top-down construction
  - difficult to control by maintenance (reprofiling)
  - Crossrail spec can be achieved
  - some evidence (not shown here) that PV allows rail to “find its own way” and settle far better than other NB trackforms
- shorter wavelengths (30-1000mm) controlled well with reprofiling and close control of spec.
- shortest wavelengths (<30mm) require running-in or another form of grinding

Conclusions

- long wave irregularities should be assessed from a long, continuous measurement
  - records here are generally > 500m; sometimes shorter on metros
- CAT offers a good way of making infrequent measurements of a few hundred metres and a few sites (demonstrated elsewhere, IWRN11 and IWRN12)
- RCA offers a method of measuring hundreds of metres routinely with satisfactory accuracy at several km/h
- irregularities of >1m wavelength are best controlled by laying good quality slab track
- irregularities of 30-1000mm can be controlled well by conventional grinding (also with selection of trackform and other methods)
- irregularities of <30mm wavelength typical increase as a result of reprofiling: alternative reprofiling methods
- to control irregularities, specifications for construction and maintenance must be monitored satisfactorily