BOMAG Vario BW 213DH4 BVC/P Roller/Compaction Tests:

Draft of report.

Current version: Revision "F"

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1.0 BACKGROUND

The Trent Valley Four Tracking Trial was set up by Paul Strange, Head of Track Geometry - West Coast Engineering, Network Rail to Test the Bomag Vario 213 roller's ability to suitably consolidate bottom ballast for a railway environment, and additionally, to compare methods of measuring the achieved stiffness.

WCRM (West Coast Route Modernisation) programme team is responsible for providing full construction for both plain line and Switches & Crossings (S&C) works.

The goal is to achieve the combination of not only sufficient but also uniform stiffness of bottom ballast. This is particularly important at S&C locations due to the length of the concrete sleepers. The current method of compaction, Triple Whacker combination followed by 2No**.** S&C Tampers working side by side (Tandem Tamping), in combination with 2No. Dynamic Track Stabilisers (DTS) is expensive and also can prove time consuming to complete the work within tight timescales. In addition the scarcity and availability of this equipment can be difficult.

If a method could be found to adequately compact the ballast prior to installing the sleepers and rail then the need for Tampers and DTS could be removed. If both sub grade and bottom ballast can be uniformly consolidated to a suitable and uniform stiffness on plane line, it should be possible to achieve higher track opening speeds of 50/80mph without DTS and Tampers, with consequential savings of time and considerable expense.

Previous attempts to trial the Bomag had proven inconclusive. During these trials hard data regarding the stiffness will be obtained using both:

- Plate Bearing Test Equipment (Sandberg) - giving Ev_2 values
- Light Drop Weight Tester (ZFG2000) (Grant Rail) - giving Evb values

These will be assessed in conjunction with the print-outs from the Bomag Vario 213 – giving Evib values

Latterly the use of either load cells or vibration meters was considered, although on exploration and due to the tight time scales this was deemed not feasible. This is still being explored for use at any further trials.

The trail area will be fully surveyed before the trials begin and at every stage of spreading and compacting to monitor consolidation/displacement.

Particle Size Distribution tests will be undertaken on samples of the ballast before and after compaction to ascertain if significant breakage/crushing takes place.

2.0 TECHNICAL DESCRIPTION

The system is essentially a road roller fitted with an automatic control system that varies the download force and angle in proportion to the stiffness of the sub grade. It will treat high spots as hard spots, and minimise its downward forces, and low spots as soft spots, and maximise the downward forces. The resultant profile is then levelled using a laser controlled bulldozer, and the Bomag process repeated until the sub grade is of both uniform level and required stiffness. The Bomag is then used to compact the track ballast.

The Bomag Vario 213 is designed to consolidate stone. The Bomag Vario 213 applies vibration at a frequency which "liquefies" the stone layer, causing the re-alignment of the individual particles which, in conjunction with the dead-weight loading results in consolidation of the layer. The frequency of the vibration is similar to that produced by the DTS but the DTS will over consolidate high spots whereas the Bomag will produce even consolidation.

The Bomag operational speed is approximately 2.5min/50metre

This Bomag process is already in use on the European Railways for preparing the sub grade formation, but not for ballast, it is believed this may be due to concerns over possible excessive crushing, which will be examined as part of the trial.

The following is extracted from DIN 18134, which can be found in Appendix K.

German sub grade specifications:

120 MN/m² for high speed tracks (< 230 km/h)
100 MN/m² for railway new construction, speeds of 120 km/h - 160 km/h
80 MN/m² for railway new construction, speeds of 50 - 80 km/h

For maintenance:

Speed < 230 km/h: at least 80 MN/m²
Speed 120 - 160 km/h: at least 50 MN/m²
Speed 50 - 80 km/h: at least 40 MN/m²

In addition to this the density is "a minimum of 100 % standard proctor" in Germany, whereas a minimum of 95% is required in the UK.

German Railways do not have density or stiffness criteria for the ballast layer.

Bomag felt that their BW213DH4BVC/P model would be the most suitable – this machine can also be fitted with whacker plates at the rear, and will be to the that being trialled at TV4. This machine weighs some 15 tonnes, though smaller models are available down to 8 tonnes weight. It was stated that plant routinely used on typical rail sites would be capable of lifting the Bomag machine if required as it is designed for lifting by crane.

The majority of the ongoing S&C work for WCRM is on green-field sites at Rugby, Trent Valley 4-Tracking, and Milton Keynes thus, unlike some railway sites, road access will not be an issue.

3.0 TRIAL LOCATION

It was initially agreed that a trial on the S&C assembly area at TV.4's main depot at Lichfield would prove if the Bomag technology was suitable for Network Rail (NR) purposes. This was subsequently re-located to a section of the main works at Huddlesford Embankment.

This was constructed with a Class 1 embankment fill material, a Reddish Brown Sandstone Ex: RMC – Weeford Quarry and has a maximum height of 5.5m. This is overlayed with 450mm of 6F2F, capping layer for railways, from 2No. sources, Tarmac – Cliffe Hill Quarry and Bardon Aggregates – Bardon Hill Quarry.

Bomag very kindly agreed to provide a new machine for this work, which would be managed and controlled by the NR/TV.4 team. The trials would consist of separate sub grade and ballast compaction trials, using, on the ballast the traditional NR methods of

i) standard roller
ii) tractor mounted whacker plates
iii) remote controlled triple whacker plates

followed by

iv) the Bomag Vario 213 with vibration only
v) the Bomag Vario 213 including its own whacker plates.

With iv) and v) trialling various combinations of vibration amplitudes and whacker plate settings.

These tests should take place on separate, adjacent strips of the trials site split into lanes.
See Appendix A

It was agreed that BOMAG would arrange for its own staff to drive the machine, and that N.R. TV.4 team would make all the necessary arrangements and preparations, including H&S issues etc.

4.0 SITE TRIALS

Tuesday 24.07.2007

Plate bearing tests carried out on capping layer.
(See Appendix E for results).

Wednesday 25.07.2007

Bomag on site and initial trails carried out on capping layer, while 150mm layer of ballast was unloaded.
Several runs trailed to familiarize machine settings and map sub grade uniformity and stiffness. See Appendix G
Level survey then carried out with assistance of GPS for half chord positions, ensuring pre and post values taken in same locations. See Appendix B

Thursday 26.07.2007

Torrential rain through out day stopped progress due to the possibility of ballast being compacted into sub grade. No Bomag testing achieved. A plate bearing test was undertaken on the previously laid & compacted track ballast to provide a "calibration reading" to facilitate the set-up procedure for the Bomag.

Friday 27.07.2007

A length of ballast 150mm deep was laid the full 10m width of site and was compacted in stages using "Bomag Vario 213" roller. The site was split into 50m sections and each section divided into lanes. See Appendix A
A level survey was completed before and after compaction. Ballast compaction was also accessed using plate bearing test equipment and light drop weight tester (ZFG2000). Samples of ballast were taken after compaction for Particle Size Determination. See Appendices B;D;F & H.

The table below details the Bomag Vario 213 settings regarding the vibration amplitude and direction and an indication of the effective depth of construction being tested.

"Bomag Vario 213" machine stage setting.	
Stage 1 – horizontal vibration (0mm amplitude). No mapping graph produced as no return signal available.	No measuring depth
Stage 2 – angled vibration (0.7mm amplitude). Equivalent to plate bearing test equipment, and EV2.	Measuring depth around 650mm below surface
Stage 3 – angled vibration (1.1mm amplitude.	Measuring depth around 1m below surface
Stage 4 – angled vibration (1.5mm amplitude.	Measuring depth around 1.5m to 2m below surface
Stage 5 – virtually vertical vibration (2mm amplitude).	Measuring depth greater than 2m below surface

The tables below, and within the text, detail the trial location, depth of ballast compacted, Bomag setting for vibration; whacker plates and relevant print-out Reference.

Section A – 184280 to 184330		
150mm ballast layer.		
Lane	**Bomag Vario 213 Stage**	**Bomag Vario 213 graph**
5	1 pass stage 2	
4	1 pass stage 2, following by stage 1	A2

Section B – 184330 to 184380		
150mm ballast layer.		
Lane	**Bomag Vario 213 Stage**	**Bomag Vario 213 graph**
5	1 pass stage 2 with plates (55Hz) and 2 passes stage 3 with plates (55Hz).	A3 & A4 (stage 3 traces)
4	2 passes stage 4 with vibration plates (55Hz), 3rd pass stage 2 with vibration plates (55Hz)	

Section E – 184480 to 184540		
300mm ballast layer.		
Lane	**Bomag Vario 213 Stage**	**Bomag Vario 213 graph**
5	4 passes stage 4, 5th pass stage 2 with vibration plates (55Hz)	A5 (final trace)
4	1 pass stage 5, stopped due to signs of ballast crushing. Reset, 2 passes stage 4 and 1 pass stage 2 with vibration plates (55Hz).	A6 (final trace)

Section E – 184480 to 184540		
300mm ballast layer.		
Lane	**Bomag Vario 213 Stage**	**Bomag Vario 213 graph**
3	4 passes stage 4, 1 pass stage 2 with vibration plates (55Hz), final pass stage two without.	A7 & A8 (final traces)

Saturday 28.07.2007

No “Bomag Vario 213”, plate bearing and light weight drop testing.
Level survey carried out before and after tractor mounted vibration plates completed section 2 (184380 to 184330), lanes 1 and 2. See Appendix B
Buckinghams, the contractor, continued to import and spread ballast during the morning.

Monday 30.07.2007

Outstanding testing and level surveys were completed.
It was arranged with Buckinghams that another 300 layer of ballast would be laid for further analysis.
While waiting for additional ballast, “Bomag Vario 213” was used to map uniformity and compaction on three sections which had been consolidated using standard methods.
Plate Bearing test were also undertaken. Samples of ballast were taken after this standard compaction for Particle Size Determination.
See Appendices F & H.

Section D – 184430 to 184480		
300mm ballast layer.		
Lane	**Bomag Vario 213 Stage**	**Bomag Vario 213 graph**
2 (Compacted in two 150 layers using standard roller will no vibration**)**	2 passes stage 2	B1 & B2

Section C – 184392 to 184430		
300mm ballast layer.		
Lane	**Bomag Vario 213 Stage**	**Bomag Vario 213 graph**
1 (Compacted in two 150 layers using standard roller will no vibration**)**	2 passes stage 2	B3 & B4

Section B – 184330 to 184370		
150mm ballast layer.		
Lane	**Bomag Vario 213 Stage**	**Bomag Vario 213 graph**
1	2 passes stage 2	B5 & B6

Tuesday 31.07.2007

Additional testing was undertaken, to try and ascertain the optimum stage and number of passes required for optimum uniform compaction.

Section I – 184690 to 184740		
300mm ballast, on top of 300mm layer, compacted in two 150mm layers, using standard roller and vibration plates.		
Lane	**Bomag Vario 213 Stage**	**Bomag Vario 213 graph**
1	1 pass stage 2, 2 passes stage 4, and final pass stage 2 with vibration plates (55Hz)	C1, C2, C3 & C4

Section I – 184740 to 184780		
300mm ballast, on top of 300mm layer, compacted in two 150mm layers, using standard roller and vibration plates.		
Lane	**Bomag Vario 213 Stage**	**Bomag Vario 213 graph**
2	2 passes stage 4, and final pass stage 2.	C5, C6 & C7

Section I – 184740 to 184780		
300mm ballast, on top of 300mm layer, compacted in two 150mm layers, using standard roller and vibration plates.		
Lane	**Bomag Vario 213 Stage**	**Bomag Vario 213 graph**
1	2 passes stage 4.	C8 & C9

5.0 EXECUTIVE SUMMARY

- Results from Bomag readouts indicate that the equipment is capable of undertaking all the operations required of it; mapping of sub-grade and improving stiffness if needed; compacting, and mapping ballast in up to 300mm layers to produce a uniform stiffness in excess of the recommended minimum value 80N/mm^2.

- Test results from Plate Bearing equipment indicate that the Bomag is more than capable, under these conditions, of achieving the minimum recommended stiffness in the ballast layer. See Appendix F

- Test results from the Light Drop Weight Tester indicate that the correlation factor between Evb and Ev2 for ballast is likely to be in the range 2.5 to 3.0 rather than 2.0 to 2.5 suggested for sub grade material. Concerns regarding this test, using a 300mm diameter plate on a 50mm nominal single sized material, with the possibility of not achieving a level and even bearing did not feature or compromise the test. This test method has advantages over the Plate Bearing Test in that it proved to be reasonably portable and time efficient. Typically taking under 5mins/test as against 25 mins/test and no site plant required as kentledge.

- Results indicate that "placed" ballast achieves a reasonable stiffness and compaction by the Bomag enhances stiffness beyond that by conventional methods. The exact settings of the Bomag need to be validated to obtain the most effective compaction method. Care must be taken not to have too high a setting, as this could result in the ballast being crushed. Initial assessment of the Bomag print-outs indicate that 2No. passes at stage 4 produced in excess of the recommended minimum stiffness of 80N/mm^2. See Appendix G

- Consideration must be given to the source and type of sub grade material and ballast with regard to characteristics in terms of bearing capacity.

- Results from level survey proved inconclusive on the 150mm layer both for the standard compaction methods and the Bomag. Observations on site indicated ballast flow in the direction of travel, leaving a ridge at the end of each test run and, in addition, the initial spreading of the material would impart a degree of consolidation and this resulted in it proving difficult to measure actual settlement.. Results on the 300mm layer were more conclusive. The consolidation as spread was still a factor but the settlement was of a sufficient magnitude to be measured. Measurements indicated that the Bomag returned much higher settlement figures than the standard methods.

- Results from PSD tests indicate no significant deterioration of the ballast – with all post compaction tests showing compliance with the specification requirements.
  See Appendix H

6.0 RECOMMENDATIONS

- Vibration monitoring on further sites to check whether the Bomag applies sufficient vibration to the full depth of the 300mm layer, leading to consolidation of the full depth rather than the upper section.

- Consideration depth of layers and methodology used to lay used by conventional methods together with further testing., e.g use of grader instead of bulldozer.

- Possibility of using GPS might be introduced for future trials & testing. This would enable the Machine Operator to control where the New Track is being constructed.

- Plan early to alleviate any Safe Systems E.g. Method Statements, Risk Assessments & Access etc.

- More testing on conventional methods, for comparison:

  (i) Hand or remote controlled Triple Whacker Plates
  (ii) Tractor drawn Whacker Plates
  (iii) Standard Roller

- Further comparative testing between Plate Bearing and Light Drop Weight Tester if it is intended that the LDWT is to be a standard test method. This to be on sub grade aswell as ballast.

- Consideration must be given as to the suitability of the Bomag in the vicinity of bridges; culverts and tunnels.

- Considerations as to the criteria to be adopted. Should the current recommended minimum value 80N/mm^2 be maintained and is there to be, as in Germany, a minimum value for the sub grade.

7.0 PARTICIPANTS

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8.0 ABBREVIATIONS

WCRM - West Coast Route Modernisation
(S & C) - Switches & Crossings
NR – Network Rail
BOMAG – Bomag Vario 213
PBT - Plate Bearing Test Equipment (Sandberg)
LDWT - Light Drop Weight Tester (ZFG2000) (Grant Rail)
DTS – Dynamic Track Stabiliser