Single Drum Rollers with Polygonal Drum

Research results, application recommendations and construction site practice

1 Introduction

Increasing the compaction performance of soil compaction equipment has always been a primary aim in refining existing machine technology. The focus of this matter has traditionally been more on the physical size of amplitude or static linear load of the drum. BOMAG has completely re-evaluated and implemented this construction industry requirement with the development of the polygonal drum. Due to the excellent introduction of the compaction energy generated by the drum this drum shape can open totally new performance ranges when used appropriately. The main advantage of the polygonal drum is the excellent depth effect which enables these machines to be used especially for post-compaction of sub-soils or to increase the thickness of layers to be compacted by up to 100%.

2 Polygonal drum

The polygonal drum consists of three axially adjacent octagonal elements which are arranged in a staggered position to the neighbouring segment. Laterally welded rings prevent the drum from tipping, if the middle element is standing exactly on its edge, and thereby enables quick transport travel on solid sub-soils (Fig. 1).

Unlike conventional drum forms the polygonal drums have an excellent self-cleaning effect so there is no need to use scrapers.

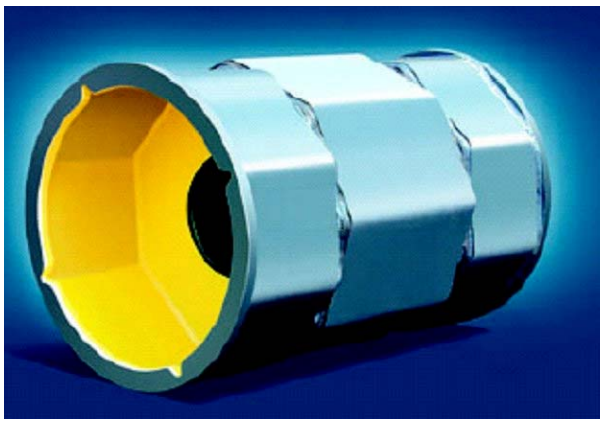


Fig. 1: The form of the polygonal drum in detail

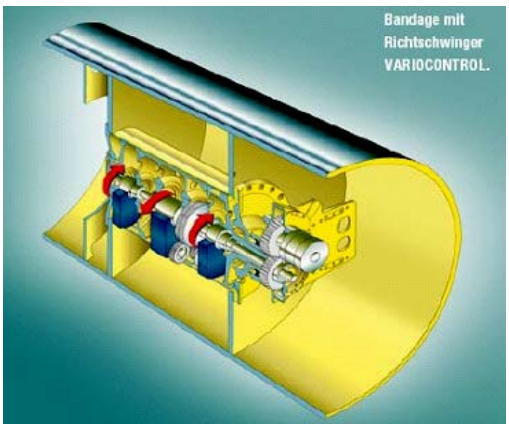


Fig. 2: VARIOCONTROL ensures maximum compaction energy

The directed vibrator developed by BOMAG (Fig. 2) is used with the single drum rollers with polygonal drum. This new type of self-regulating system recognises the energy requirement needed for the compaction process and regulates it automatically. The VARIOCONTROL system works on the basis of the interaction between the drum and the stiffness of the soil material to be compacted. Compaction energy is automatically optimised by utilising acceleration signals measured on the drum. This adaptation means that the maximum compaction energy possible can be introduced into the soil at any time without the drum skipping into disadvantageous jump operation.

3 Mode of operation

Unlike a round drum where the effective force direction remains constant during the rolling process, the special compaction effect of the polygonal drum lies in the permanent changing of its direction of force from plate to wedge segments and vice-versa. The plate segments compact by introducing concentrated vertical pressure forces. The wedge segments create a deformation effect in the soil where pushing forces are introduced by the high linear load and the rotational movement of the drum which displace the soil locally (Fig. 3).

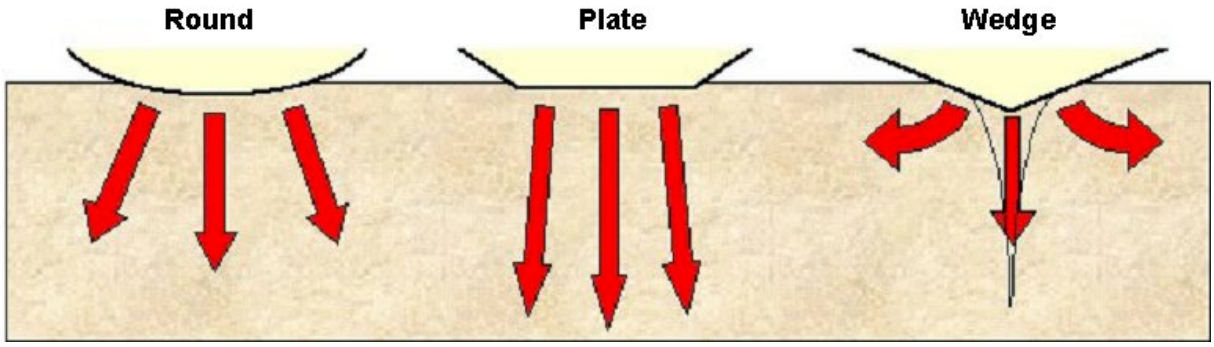


Fig. 3: Effective directions of force with round and polygonal drums

The combination of peak pressure and pushing forces results in kneading and de-tensioning of the soil which promotes compaction. This effectively prevents wedging of soil particles which can inhibit compaction. Since this does not result in the formation of compacted covers, the polygonal drum creates the prerequisite for a great depth effect (Fig. 4). Because of localised de-tensioning in front of and behind the polygonal drum wedge, the soil in the contact area gets “softer” and trapped air can escape. Distinct plasticizing occurs, whereby the global contact force between the drum and soil is so greatly reduced that operational conditions such as “jumping”, “tumbling” or “chaotic behaviour” do not occur.

Together with the absence of a bow wave occurring in front of a round drum and with the excellent positive forward drive, this effect enables a slower travel speed with higher compaction and depth effects in combination with a drastically reduced number of passes.

For the reasons already mentioned, this drum type is in principle suitable for compaction of all soil types, but because of the special interaction between plate and wedge segments on coarse particle soils you should be aware of the fact that there will be strongly loosened surface zones. Accordingly, the advantages of the single drum rollers with polygonal drum really come into play on high lift heights or when post-compacting subsoils. The distinct formation of a surface pattern on fine particle soils causes better interlocking of the layers on dam fills or on sloping layers (landfill construction).

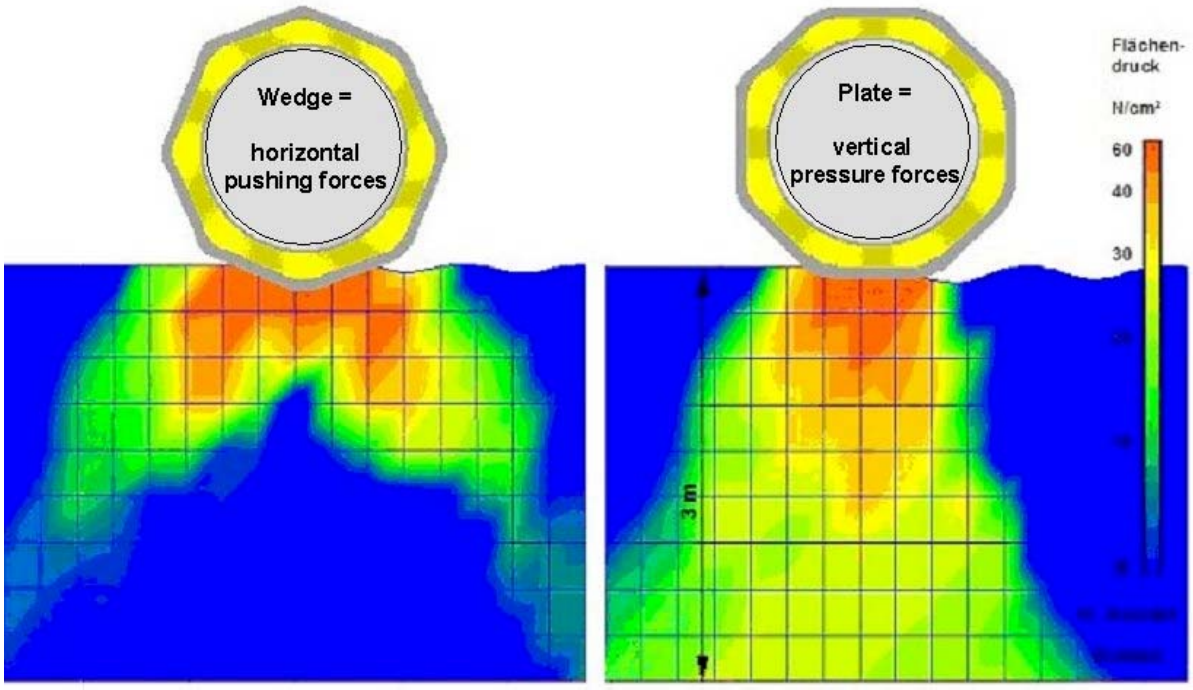


Fig. 4: Tension measurements in the soil reveal the interaction of wedge (= pushing forces) and the plate (= pressure forces) directed into the depth

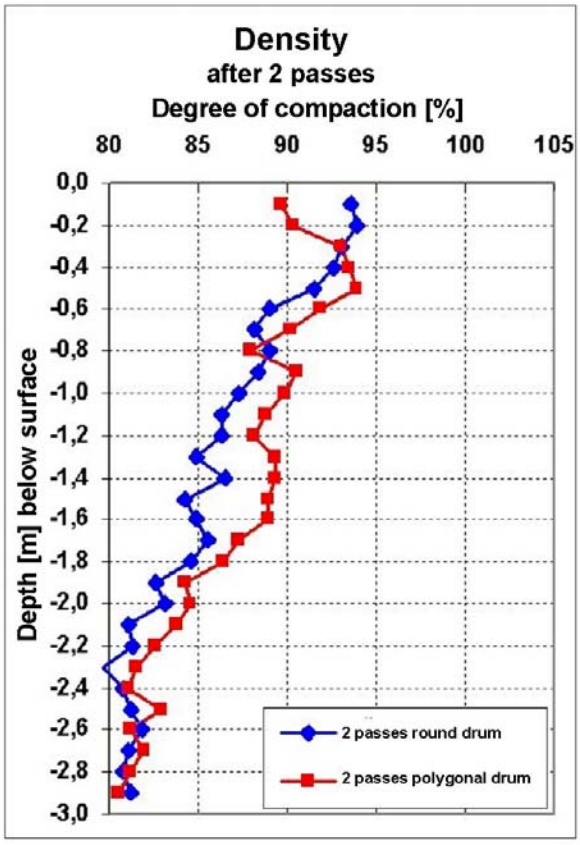
4 Completed tests

4.1 Compaction of a 3 metre lift height

A trial area with 3 m layer of an extremely silty gravel (GU*) was laid to test the depth effect of a 25t single drum roller with polygonal drum in comparison to a single drum roller of the same type with a round drum. The layer was laid with a bucket excavator without pre-compaction. The following geo-technological measurements were carried out for each drum type at different depths after 2, 4, and 8 passes:

- Settlement measurements with a levelling device
- Standard penetration test
- Density analyses with a double probe at 10 cm intervals, down to 3 m
- Density analyses with a sand substitute procedure at 50 cm intervals, down to 3 m
- Compressive stress measurements at 50 cm intervals

All procedures seem to confirm the effect described in section 3 for the drum types examined. The densities detected with the double probe are represented in Fig. 5 and Fig. 6 as examples. The double probe is an isotope probe, type DS 100 LPC. Two measuring tubes inserted into the soil (sender and receiver) measure the density of the soil material between the tubes, always at 10 cm intervals, using radiation absorption (caesium 137 radiator).



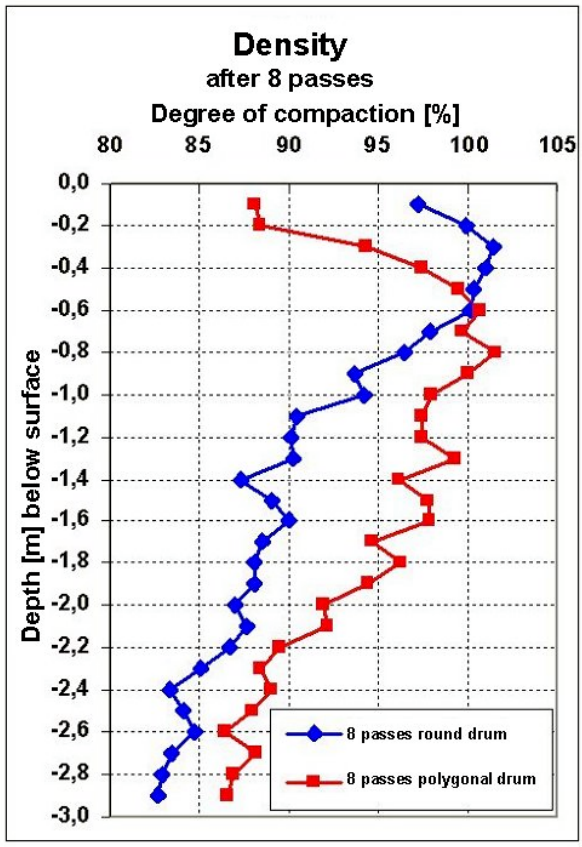


Fig. 5, Fig. 6: Compaction degrees attained at different depths

4.2 Improvement of subsoil by post-compaction

The depth effect of the polygonal drum was systematically examined within the context of the pending road construction scheme B 95, south of Leipzig. At the forefront of the road construction scheme there was initially a 5 m deep subsoil improvement of the existing loose to fairly dense layered, extremely silty to gravely sand. The significant depth effect of the 26t polygonal drum roller BW 225 D-3 BVC was proven by a trial compaction of a test area within the area of the planned road, which led to the development of an alternative to the planned soil exchange. Tests were carried out by FUGRO Consult Leipzig (Fig. 7, Fig. 8). Five independent procedures were used to evaluate the bearing conditions of the subsoil before compaction and to evaluate the compaction depth and change in compaction after 3 and after 8 passes:

- Analysis of the degree of compaction every 0.50 m in depth
- Analysis of the dynamic E-modulus with the light drop-weight device
- Analysis of the standard penetration test resistance
- Analysis of the static penetration test resistance
- Surface levelling for settlement measure-ments

Fig. 7: View of the test and the depression of the surface after 8 passes with the BW 225 D-3 BVC with polygonal drum

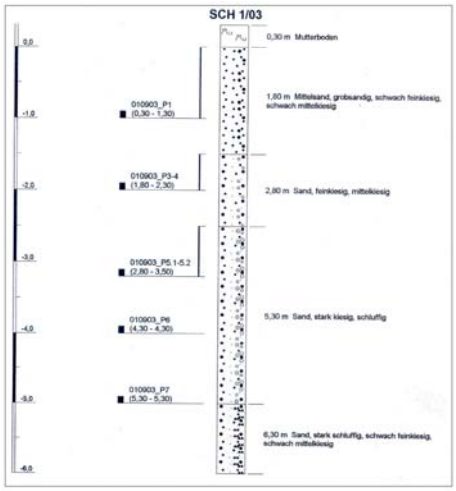


Fig. 8: Soil profile of the test field

All procedures show signs of a uniform result. In summary it can be established that a degree of compaction of > 100 % can be proven at depths of 0.7 m to approx. 2.5 below the compaction level. At 2.0 – 4.0 there is still a clear increase (7-8 %) of compaction (Fig. 9, Fig. 10). From a depth of 4.0 m under the compaction level, the compaction effect decreases and comes close to the natural magnitudes without compaction in the area from 4.0 to 5 m under the compaction level. Loosening of the soil directly under the compaction level down to a depth of 70 cm is significant for the special depth effect of the polygonal roller. On the one hand loosening is caused by the movement of the drum and the high stress of the soil; on the other hand it is caused by the typical loosening sensitivity of sand. The decisive factor is the deep and clear increase in compaction and load bearing capacity which makes the polygonal drum interesting as an alternative to exchange of soil.

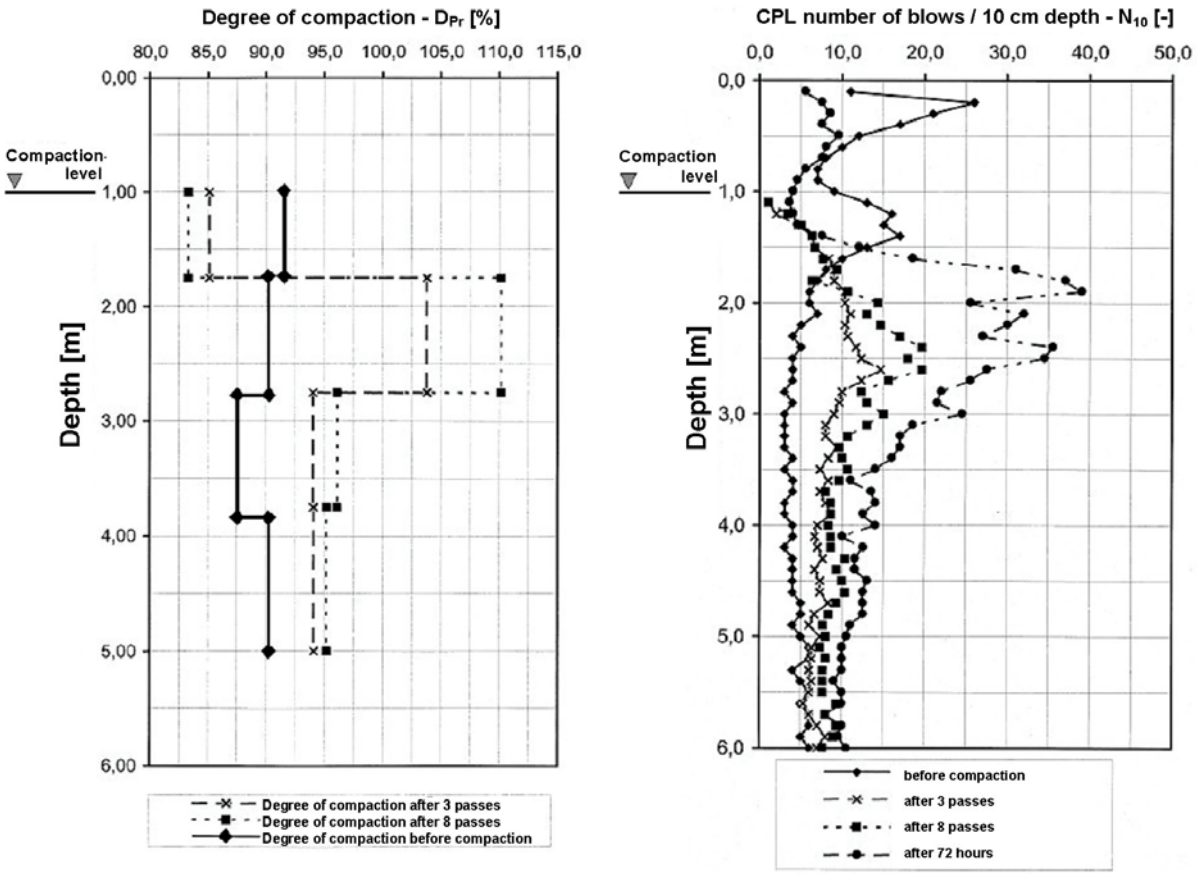


Fig. 9, Fig. 10: The increase in degree of compaction acc. to the Proctor test of the number of impacts down to 4 m below the working level is clearly recognisable

5 Completed construction measures

5.1 Runway extension at Hahn airport

Hahn airport is booming. Accordingly, in 2002, it became necessary to extend the runway. Extensive ground levelling was to be carried out in the course of earthworks. In order to be able to choose the layer thicknesses as thick as possible and still achieve perfect compaction a decision was made in favour of a 26t single drum roller BW 225 D-3 BVC with polygonal drum (Fig. 11). Layer thicknesses of up to 1.50 m on non-cohesive and up to 1.0 m on cohesive soils were thus laid and compacted. A single drum roller of the same weight class was used with a smooth drum to eliminate surface loosening of the compacted layer package which was caused by the polygonal drum. In addition to this, smoothing the surface assured problem-free drainage of rain water.

Fig. 11: Compaction of filled layers ranging from 1 m to 1.5 m at Hahn airport

Fig. 12: De-tensioning of the concrete superstructure on the A9 motorway at the Schkeuditzer Kreuz

5.2 Breaking up a concrete carriageway

In the course of renewing the A9 at the Schkeuditzer Kreuz near Leipzig during the summer of 2002 the old concrete carriageway needed to be broken up and removed. The contractor made a decision in favour of a 26t single drum roller BW 225 D-3 BVC with polygonal drum (operating weight 26t) for crushing the carriageway. The surface cover consisted of 28 cm thick non-reinforced concrete. Thanks to the power of the single drum roller with polygonal drum de-tensioning of the concrete surface was completed after 3 passes. This resulted partially in the complete destruction of individual concrete slabs as shown in the illustration or to the formation of a crack structure through the entire slab thickness (Fig. 12). The de-tensioned route section was in the meantime used as a haulage road for the construction, until removal of the concrete. In spite of considerable settlements and skewing, the stability of the substructure under the concrete slab was sufficient to provide sufficient resistance for de-tensioning the concrete carriageway.

5.3 Coarse covering for municipal waste disposal site

At the municipal waste disposal site in Leipzig-Möckern, a surface cover is currently being applied with a 50 cm equalising layer of cohesive soil and a 1.50 m thick revegetation layer. Different BOMAG single drum rollers with smooth drum, padfoot drum and polygonal drum are being used to compact the layers with a single layer thickness of up to a maximum of 50 cm (Fig. 13, Fig. 14). The surface covering on the waste disposal site has a maximum inclination of 35 % or 1:3 on the steepest construction sections. Due to the polygonal shape of its drum the BW 213 DH-3 BVC (operating weight 15t) is particularly characterised by its excellent gradeability on the soil material to be laid, even on damp soil surfaces. Furthermore, excellent interlocking with the next layer is achieved by the wash-board pattern on the surface of the compacted

soil layer, which ensures very good bonding between the individual soil packages.

Fig. 13: Two single drum rollers with polygonal drum during compaction of the equalising layer

Fig. 14: The wash-board pattern ensures good bonding between the individual layers

6 Application recommendations

The range of applications for single drum rollers with polygonal drum is explicitly represented in the following table:

Application	BW 213 DI BVC (15t operating weight)	BW 226 DI BVC (26t operating weight)	Comment
Divided according to construction task			
Post-compaction of subsoil layers	++	+++	Loosening of the surface
Compaction of high lift heights	++	+++	Only limited suitable for thin lift height
Crushing of carriageways with concrete surface	-	+++	Good support is necessary
Differentiation according to soil type			
Compaction of non-cohesive soil	++	++	Strong surface loosening
Compaction of mixed particle soils	+++	+++	Moderate surface loosening
Compaction of cohesive soils	+++	+++	Minimal or no surface loosening

Notes:

+++ very well suited ++ suitable - not suitable

7 Summary

Single drum rollers with polygonal drum expand the range of applications for conventional single drum rollers quite considerably. The great depth effect of up to approx. 4m and the versatility of this drum form are particularly outstanding, which means it can be used for compaction of nearly every existing soil type, whether it is cohesive, non-cohesive or mixed particle soil. In addition to this, the 26t design can be used to de-tension carriageways with concrete surface. As a result of the effect of the polygonal drum, the full performance capacity of this drum shape only comes into play with larger layer thicknesses, because of the detected surface loosening of the layer to be compacted during compaction of mixed particle and non-cohesive soils. If necessary, a single drum roller with smooth drum should be used to achieve the defined compaction goals, also in the areas near the surface of the laid soil layers.

8 Bibliography

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BOMAG GmbH: Research report, Wirkungs-weise der Polygonbandage (Effect of the polygonal drum), Boppard 2004