WESTFALIA TUNNELLING SYSTEMS

WESTFALIA TÜNEL AÇMA SİSTEMLERİ

P. GREB (*)

ABSTRACT

In hard-coal mines the term "infrastructure" is utilized to identify all outby operations underground. A substantial part of infrastructure is the development.

Due to this fact the importance of tunnel and roadway drivage has increased considerably during the last few years and is certain to increase even more in the future.

Ouick and economic construction are the requirements to be met. The following pages give an outline of the wide range of machines and equipment developed by Westfalia Lünen for tunnel access to new coal areas, roadheading and developing of new panels.

ÖZET

Taşkömürü madenciliğinde altyapı (infrastructure) terimi yeraltındaki dışarıyla ilişkili çalışmaları tanımlamak için kullanılır. îç yapının önemli bir kısmı hazırlıklardır.

Bu yüzden tünel ve galeri sürmenin önemi son birkaç yıl içinde önemli derecede artmıştır ve gelecekte de daha artacağı muhakkaktır.

Hızlılık ve ekonomik yapım karşılanması gereken gereksinimlerdir Bildiri Westfalia Lünen tarafından yeni kömür alanlarına tünel ulaşımı, yeni panoların galerilerinin sürülmesi ve hazırlığı için geliştirilmiş çok çeşitli makina ve ekipmanların bir özetini vermektedir.

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. INTRODUCTION

With the development of mechanization of coal getting operations and concentration of mining operations the need for improved tunnelling techniques has become more and more essential.

WESTFALIA LÜNEN, based on their experience of high speed tunnelling in the civil engineering industry, have developed suitable machinery and systems for fast tunnel access to new coal areas as well as for roadheading for speedy opening-up of new panels.

In close cooperation with leading manufacturers in the fields of drilling, loading, transport, conveying, roof-bolting, ventilation, dust suppression and air-cooling İn a first step the operations of traditional road driving technique have been combined by Westfalïa Lünen to an advanced basic roadheading and tunnelling system.

For mechanized roadheading WESTFALIA machines of the boom type are available in many forms and capacities as :

Boom Cuter Loaders of FL—type
Heading Machines of VM-type
Tunnelling Machines of WAV-type.

Fully mechanized system of tunnelling during recent years have been introduced to the civil engineering and the mining industries using powered tunnel shields of full face boring machines WESTFALIA has adpated its blade shields, extensively used in subway constructions, for application in driving roadways in coal mines.

Many years of experience and success have reinforced the WESTFALIA view that as far as sectional cutting machines are concerned, the cutting boom with axial cutting principle is the best solution (Fig. 1). For this reason, all sectional cutting machines made by WESTFALIA LÜNEN work with cross-axial cutting heads. This means that the cutting head is arranged at right angles to the boom axis and the face is worked at one side with a part of the cutting head surface • with great rate of thrust. These machines do not require support frames of cylinders for reasons attributable to the cutting process. In conjunction with these universally utilizable sectional cutting machines, WESTFALIA has always set great store by the fact that not only the loosening work but also the loading cycles are tackled perfectly and absolutely safely by the machines.

For the economical utilization of a roadheading machine, many aspects and influencing factors have to be taken into account apart from the workability of the rock. The following brief indications relating to the uniaxial compressive strength of the rock are provided as guidelines for the application of the various types of Westfalia sectional cutting machines. Thus for instance, the types FL—3R (Fuchs) and FL—4R (Dachs) can be made use of without restriction for minerals of comp-

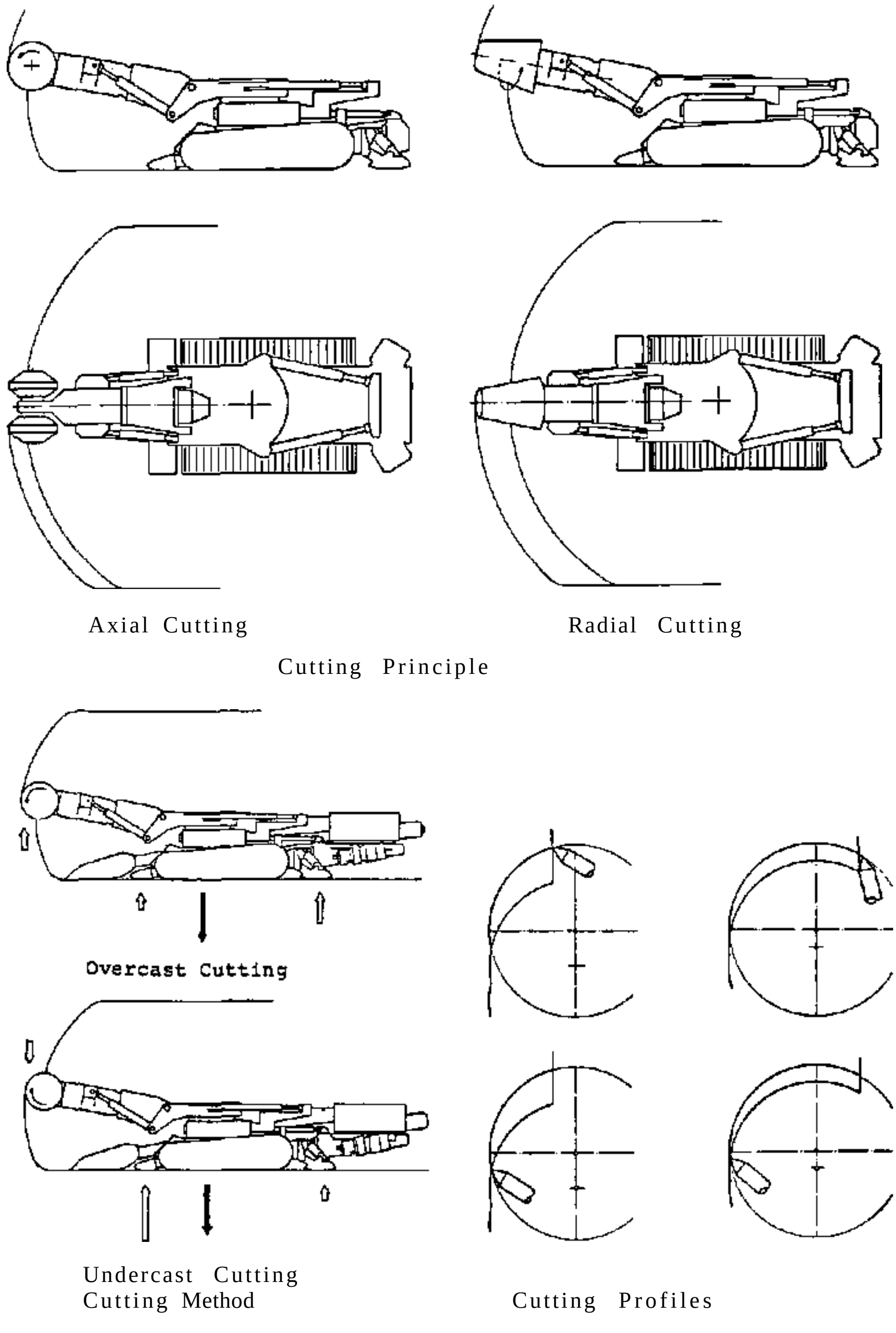


Figure 1. Cutting principle, cutting method and cutting profiles of sectional cutting machines.

ressive strengths of up to approximately 3000 N/cm^2, the Boom Cutter Loader FL-5R and FL-6R (Luchs) up to 8000 N/cm^2 and the Roadheading and Tunnelling Machines of the Wav series up to 12000 N/cm^2 Given favourable ground conditions in fact, these machines can be used economically at even higher compressive strengths too.

2. BOOM CUTTER LOADERS FL-TYPE

All Boom Cutter Loaders load over the cutting boom which is constructed as a conveyor. As the conveyor chain either drives the cutting drum or is driven separately, all these machines cut under cast.

The Boom Cutter Loader series is divided up into size categories and is exceptionally well suited for use in civil engineering and Mining (Fig. 2).

The Boom Cutter Loaders realise the principle of simultaneous loosening, loading and conveying in a particularly illustrative manner, as everything, which is freed by the cutting drum can be removed over the cutting boom. For this reason, no separate loading equipment is required. This means that these machines are extremely versatile. By means of Boom Cutter Loader it is quite feasible to select certain segments of the cross-section to be cut, to proceed with selective winning, to undercut the support frames and to achieve outstanding loading operations even when cutting below the working level.

The swivelling boom of the Boom Cutter Loader ensures an accurate cutting of the roadway section. Thu cutting drum laods the excavated material and ensures the clean cutting of the floor. The material which is free, broken up and loaded by the cutting head passes over the cutting boom and the boom conveyor to ancillary transport facilities.

The Boom Cutter Loader series are adaptable to the most varied operating conditions.

Boom Cutter Loaders Type FL—3R—40, and FL—3R—50 (Fuchs) are extremely compact and manoeuvrable machines for cutting and loading (Fig. 3). The crawler tracks of these machines are individually driven by hydraulic motors to achieve good manoeuvrability and strong penetration thrust. The slightly bigger type FL—4R—53 (Dachs) has a far wider range of action as it can cut sections of more than 18 m^2 from one stationary position. It İs used subway construction and winning of minerals of medium hardness.

The cutting heads of Boom Cutter Loaders of the FL-5R and FL-6R series (Luchs) are powered with 90/110 kW motor drives which can cut material of up to 8000 N/cm^2, i.e. coal and minerals of similar hardness (Fig. 4). A special type of the proved Luchs-mode! is the FL-6R-110 (Luchs-H 110) which can be applied for driving tunnels where the New Austrian Tunnelling Method (NATM) is applied.

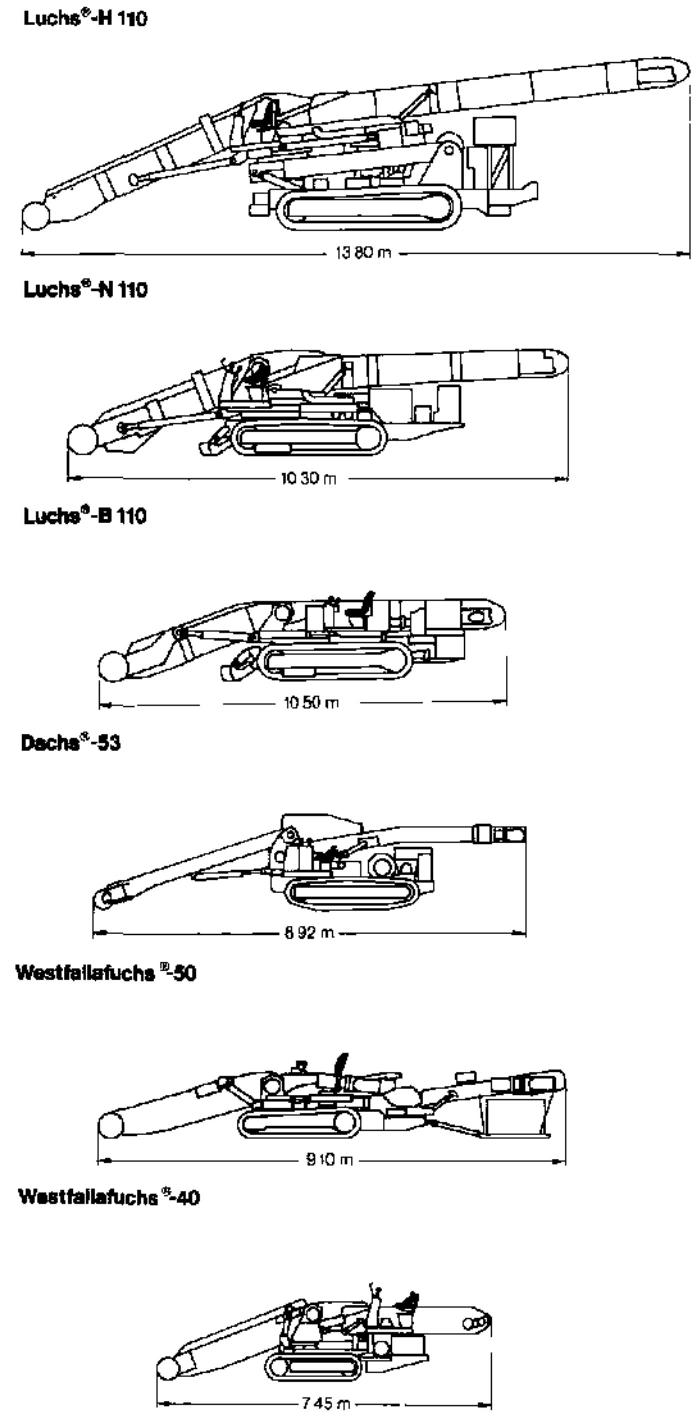


Figure 2. WESTFALIA boom cutter loaders of FL—type

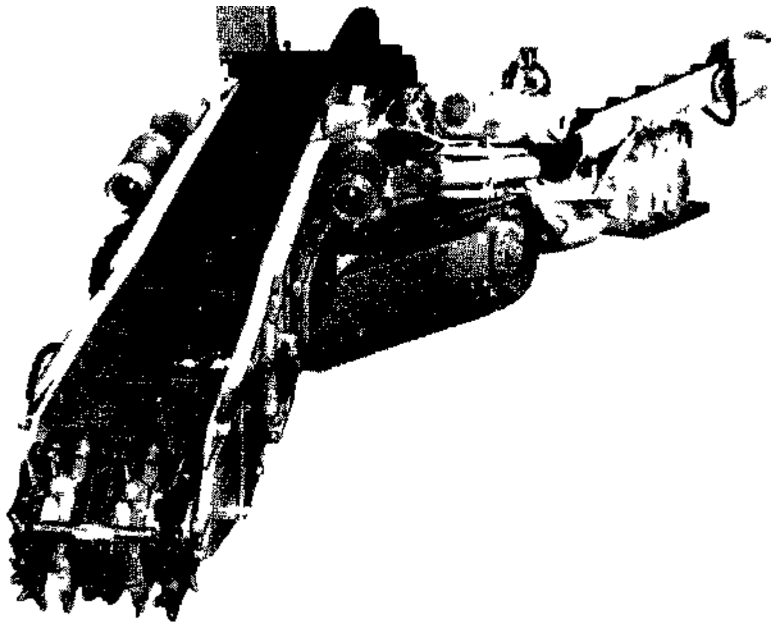


Figure 3. Boom cutter loader FL—3R—50 (Fuchs).

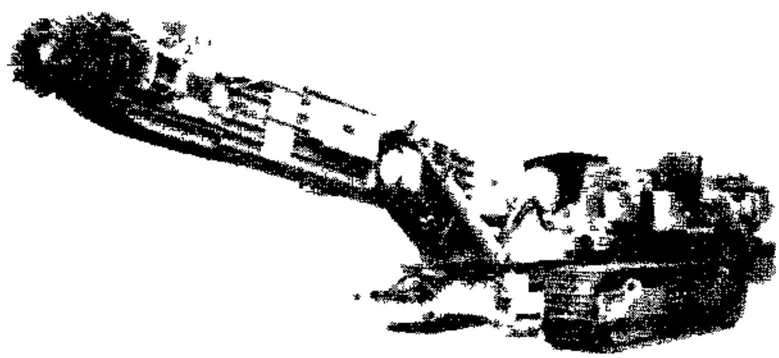


Figure 4. Boom cutter loader FL—5R1—90/110 (Luchs).

The design of the machine permits to advance the crown of the tunnel by 3.5 m at a maximum working height of 7.2 m and a possible undercut of 0.9 m.

So far, WESTFALIA LÜNEN has constructed well over 400 Boom Cutter Loaders of various types for successful operation in the mining and civil engineering industries.

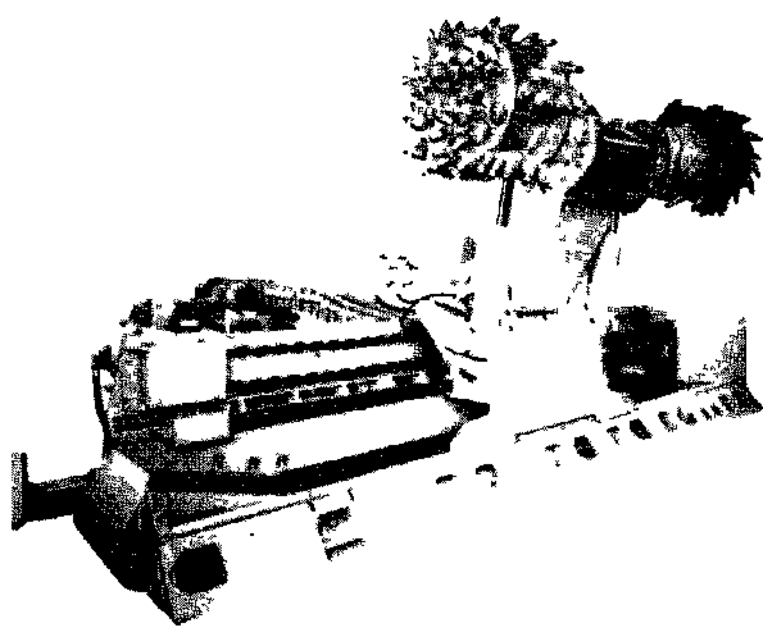
3. HEADING MACHINES VM-TYPE

Only a short time after the first successful operational trials with Boom Cutter Loaders, WESTFALIA LÜNEN began the development of a small sectional cutting machine mounted on a conveyor, which was to be suitable for the mechanisation of rise headings and the drive of coal roads.

The prototype of such a heading machine was used for the first time in 1966 for road heading in the Anna Seam of the Zollverein Colliery. This machine was used for more than six years. At the present the Heading Machine VM—E is the newest type of these machines (Fig. 5). It comprises a L—conveyor with a 90° curved pan, the machine guide, the cutting equipment, the winch, the aligning device, the advancing device and the control panel. Aself advancing support system follows the machine and at the same time provides the abutment for the shifting forces during sumping in.

The cutting drum are driven electrically with an installed output of 120 kW via planetary gears. The working part is moved on a haulage chain with a hydraulic motor. The drums can be raised and lowered by means of jacks. 90 kW are installed for the hydraulic winch and the jacks.

The working method of the VM—E is that the drums are pressed into the coal face as the hole machine is advanced by the rams. This creates the first cut which is then enlarged towards the walls of the heading and towards the roof and floor.



Figures. WESTFALIA heading machine VM—E

The overcast direction of rotation of the cutting drums enhances the stability of the machine, whereby the drums are constructed in such a manner that they load the material lying in front of the conveyor on to the pan.

The success of these machines, which drive coal roads 4.3 m wide and up to 3 m high at average speeds of 17 m/day - with recorded peak performances of 30 m/day (Schlägel U. Eisen) - resulted in a version being constructed for shortwall working.

Five such machines are in use for winning of sedimentary phosphate in Marocco height (Fig. 6). In shortwalls of 15 to 30 m in legnth and 3 m height, face advances of up to 41 m/day were recorded with net outputs of up to 2850 t/day and OMS (output per manshift) of more than 100 t/manshift.

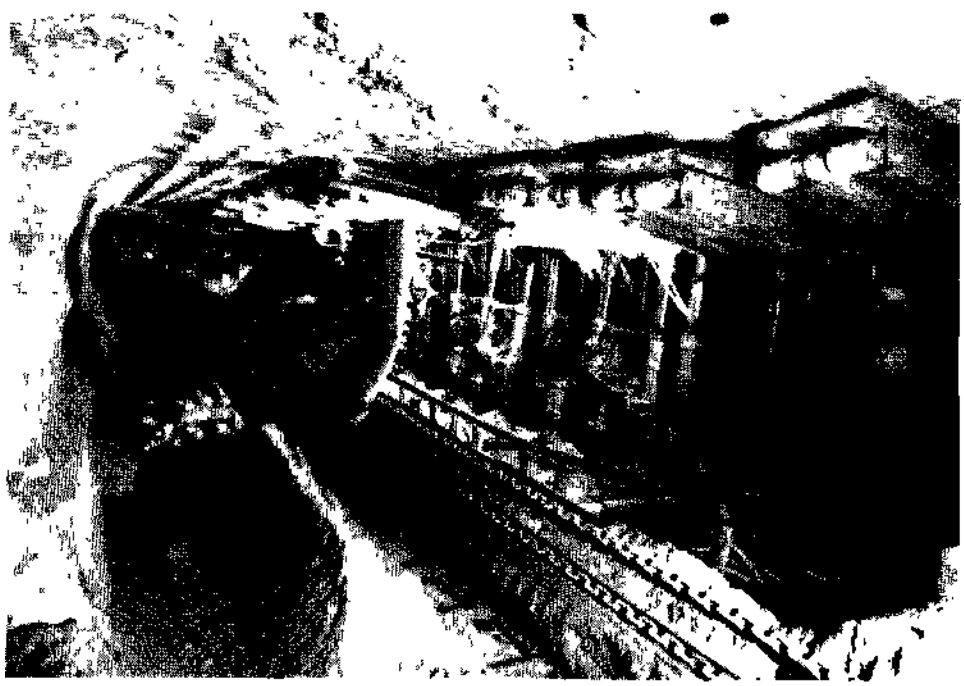


Figure 6. Heading machine VM 08 in shortwall operation for phosphate winning at Youssoufia (Marocco).

4. TUNNELİNG MACHINES WAV-TYPE

All machines of the WAV series (Fig. 7) are capable of cutting minerals and rocks with a compressive strength of up to 12000 N/cm^2 economically; even greater compressive strengths can be coped with given suitable stratification and toughness. All large crawler-mounted sectional cutting machines of this type have been equipped with a separate loading unit consisting of a loading shovel, one central or two lateral flat-link chain conveyors and special loading devices. The width of the loading

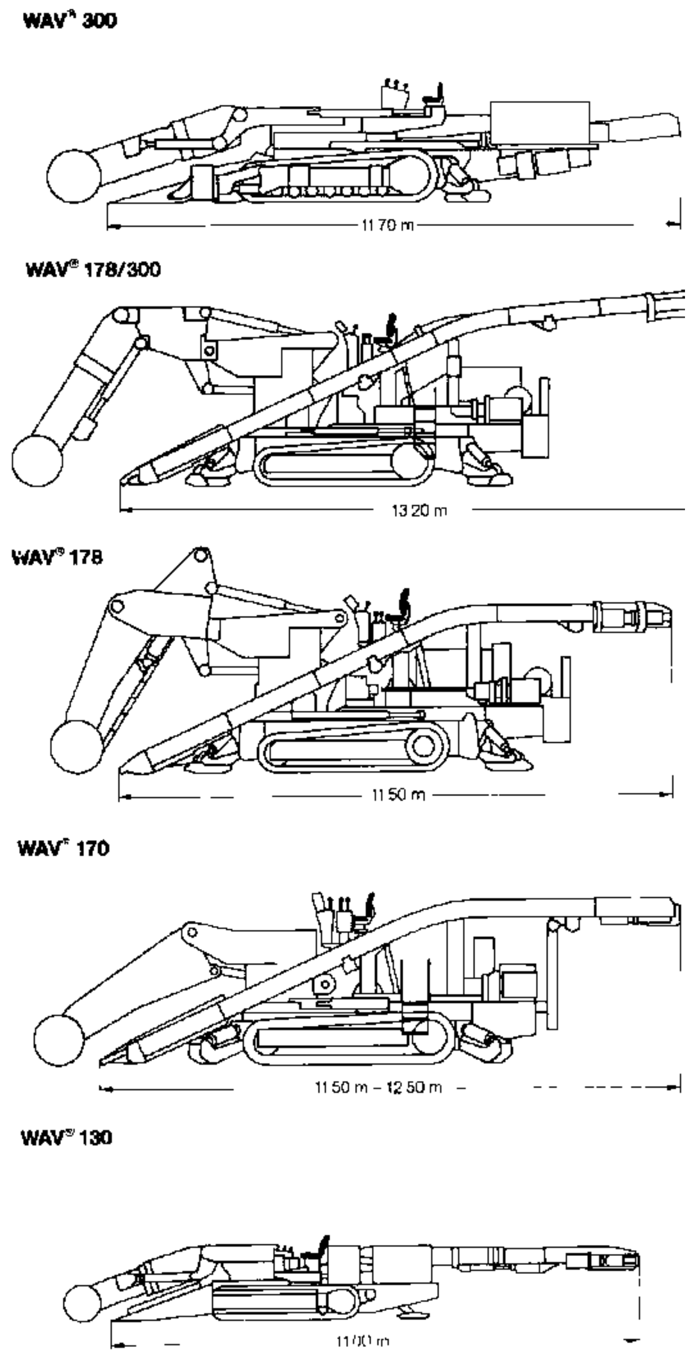


Figure 7. WESTFALIA tunnelling machines of WAV—type

unit can be adapted to conform with the on-the-spot conditions by an appropriate design or by means of additional loading aids arranged at either side of the shovel. Similarly, the fiat-link chain conveyors which are attached to the loading unit can also be adjusted to accommodate the requirements with respect to their transfer height and their transfer length. This loading system for the WAV—machines is located at the front of the crawler assembly in a vertical guidance and supported at the rear in such a fashion that the leading edge of the shovel during advancing pushes itself under the cut material as a result of its weight and its wedge shape.

All large sectional cutting machines made by Westfalia Lünen have additional hydraulic stabiliser legs, which are powered as to be able to lift the whole machine; the legs relieve the crawler assemblies and ensure that their stability is increased.

The first of these large sectional cutting machine of the WAV series the WAV 170 was put into operation as far back as 1970 for the winning of gypsum. Its simple and robust construction has proved its reliability in recent years at many sites for tunnelling and underground railway construction as well as for roadheading in the mining industry and for extraction of potash, iron ore and gypsum.

The success of this powerful roadheading and tunnelling machine led to the development of the WAV 200 (Fig. 8) which was particularly designed as roadheading machine for coal and was operated for the first time in 1975. The strong cutting head powered by a 200 kW motor is designed according to the WAV 170 principle;

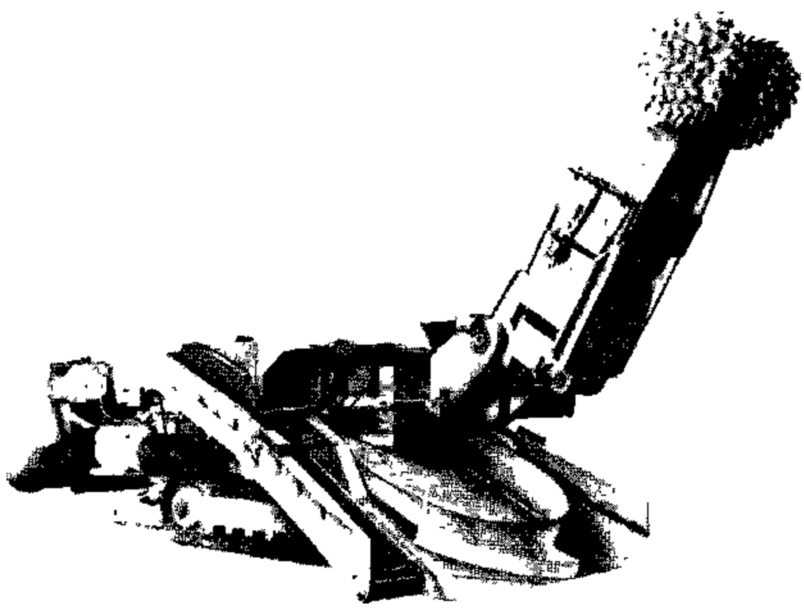


Figure 8. Tunnelling machine WAV 200

however, the cutting boom can be hydraulically extended and can be swivelled to both sides along its longitudinal axis by ± 15°. In this way, it is possible to cut with supported, stationary crawlers and so arrive at an accurate roadway profile especially at the roof.

All machines used in coal mining are constructed in such a way that they comply with the demands of underground transport as far as their dismantled unit sizes and weights are concerned. For the hydraulic units, only noninflammable hydraulic fluids and for the electrical units only flame-proof equipments are utilized.

Investigations of utilisation of sectional cutting machines in mining operations have revealed, however, that the operating time amounts to only about 66 % of the available service time, whereas the rest of the time is accounted for by relocation, inoperation and reconditioning. The break-up of the operating time showed 30 % for cutting, 40 % for supporting and 30 % for standstill, maintenance and repair. These figures indicate that the drivage speed can only be increased in a limited way be an amelioration of the cutting performance and that a reduction of time needed of supporting is a more prospective approach.

A considerable improvement in overall drivage performance can be expected when supporting operations are separated from the cutting operations and both the operations take place at the same time.

Following the successful combination of a sectional cutting machine and a blade shield in a circular tunnel drivage, a similar combination was developed for an arch-type roadway drivage with the WAV 200 and the prototype put into service in 1979 at the Heinrich Robert Colliery (Eastern Ruhr Area). As a result of the limited space available in the shield due to the incorporation of the WAV 200, the loading and conveyor system previously used could not be accommodated. The loading system designed specially for this combination comprises two transversely arranged loading conveyors with extended flights, which pass on the cut material to a scraper chain conveyor centrally located in the shield (Fig. 9).

Table 1 - Typical Results of Fully-mechanized Roadway Drivage with WESTFALIA Bladeshield Tunnelling System

	Prototype Jan.-April 1980	Industrial July 1981
Advance per day (m/day)	9.03	13.18
Excavated rock (m^3 /day)	195.4	279.5
Rock excavated per man-shift (m^3 /MS)	8.4	12.7
Pick consumption (p/m) per m of advance	0.65	0.59

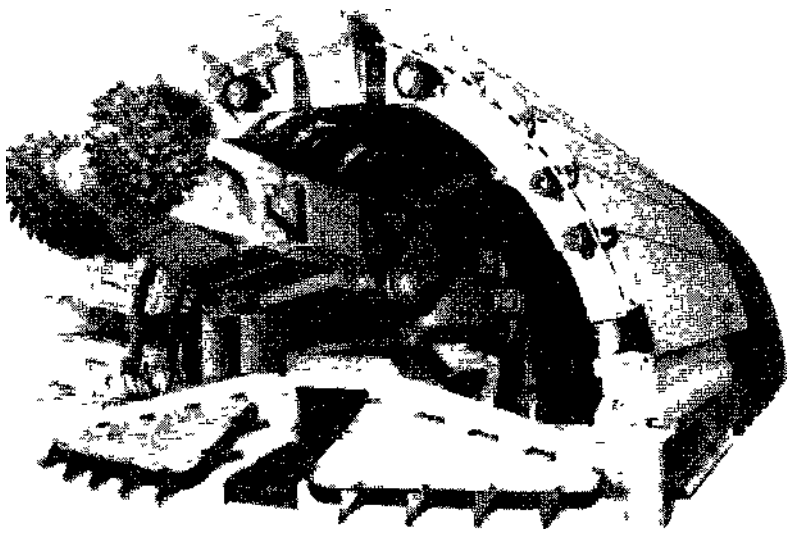


Figure 9. Blade shield with integrated sectional cutting machine and loading assembly for roadway drivage in coal mining.

Although shield tunnelling has been a feature of civil engineering work for quite some time in circular cross sections where segmented lining of İn situ concreting İs used behind the machine acting as abutment for the shield, only the Westfalia blade shield concept for horseshoe sections can be regarded as one of the first appropriate applications of shields to mining tunnelling.

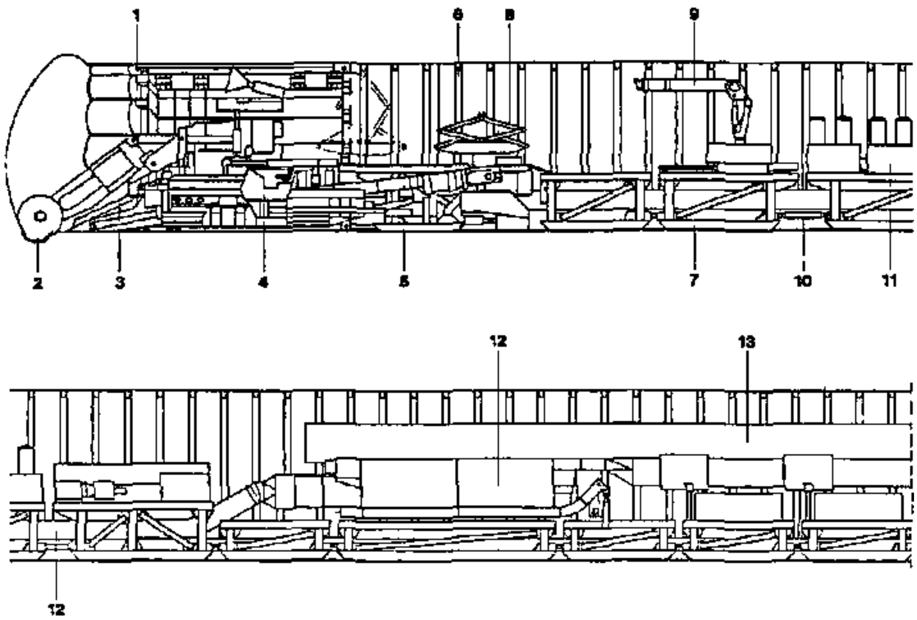
The blade shield carcass is constructed of a number of single blades which can be advanced with their own hydraulic rams (Fig. 10). For protection of the excavated roof, the side walls and the floor the blades are advanced one at a time relying on a friction between the remaining blades and four bottom blades. When all these moved forward with the combined force of the blades rams, using the friction of all the blades of the carcass for reaction against the ground so that no other abutments is required. The blade shield is a sort of preliminary powered roadway support permitting to separate cutting and supporting operations in a roadway drivage thus reducing considerably the machine's standstill time and enabling the erection of arches behind the machine under the cover of the rear blades.

This shield is further distinguished form normal shields by the fact that the frame possesses telescopic segments at various points of its periphery, which given the effect of rock pressure can yield against a constant, hydraulic resistance and in this way adapts to the ovnergence of the surrounding rock without destruction. The principle task is in essence to be able to extend the loosening work at the face throughout the overall working time and to separate it completely from the support work, that is to say, to bring about a paralleling of the two operations. In this way,

Figure 10. View of rear side of blade shield showing two floor blades and three sidewall blades' extensions for protection of support setting.

the time-oriented degree of utilization of the mechanical equipment is increased. The drivage speed is enhanced and the specific costs lowered (see Table 1). With a distance between support units of 80 cm, 9.03 m/day were achieved on average during prototype trial 1980. Peak performances of 33 minutes for one meter of roadway were arrived at during 1981 showing that drivage performances of 20 m/day and more are feasible. The advanced technique of cutting and supporting with these powered blade shields permitted to create optimal working conditions by effective dust suppression and cooling equipments as well as centralized monitoring of all operations (Fig. 11).

The good results achieved by the loading unit of the combination of tunnelling machine and blade shield led to a similar design with the most powerful WESTFA-



1 Blade Shield
2 Tunnelling Machine
3 Loading Assembly
4 Control Stand
5 Chain Conveyor
6 Support Arches
7 Structure for Ancillary Equipment
8 Support Setting Device
9 Support Manipulator
10 Coupling Cylinder
11 Power Pack
12 Dust Extraction Equipment
13 Ventilation and Cooling System

Figure 11. Complete mechanized roadway driving system with shield and tunnelling machine.

LIA tunnelling machine the WAV 300 (Fig. 12) which can be equipped with a 300 kW motor for the cutting head. These machines are designed to be operated with intrinsically-safe electronic control units which are in the position to ensure that the actual cutting profile has a difference of only a few centimeters to the indicated roadway section.

The newest development in this field is the mining and roadheading machine WAV 130. This is a very compact and powerful selective cutting machine with 130 kW installed power on the cutting heads. The WAV 130 is designed both for production mining and for tunnel, gallery, or roadway driving. Sumping-in is achieved by advancing the superstructure and the boom by hydraulic cylinders without usine the crawlers. The first cut is made at the floor. The machine is, then, placed in position for cutting the working face by hydraulically pushing the loading apron with the conveyor assembly in the su m ping hole so that the cut material can fall onto the loading apron as the extraction proceeds. The cutting head can cut material of up to 10 000 N/cm^2. The maximum excavated cross section amounts to 20 m^2.

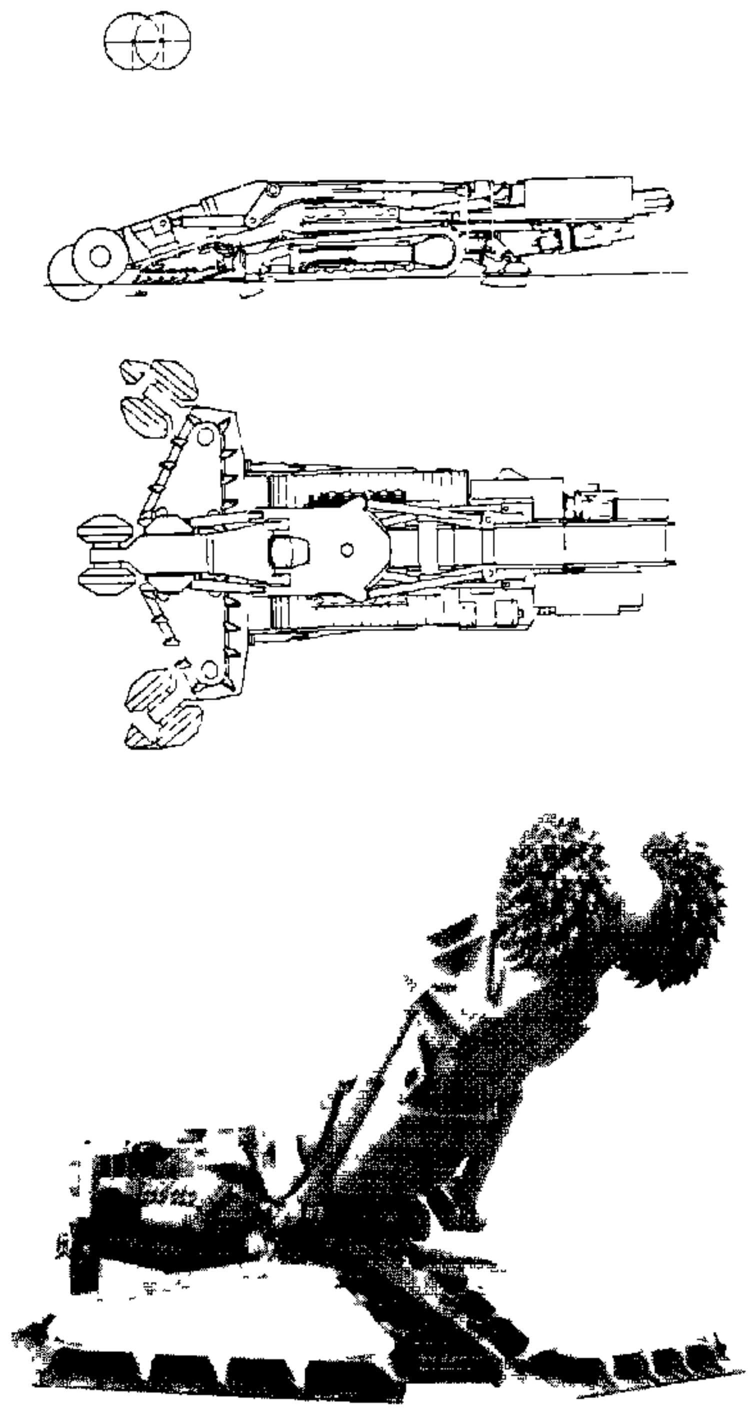


Figure 12. Tunnelling machine WAV 300.

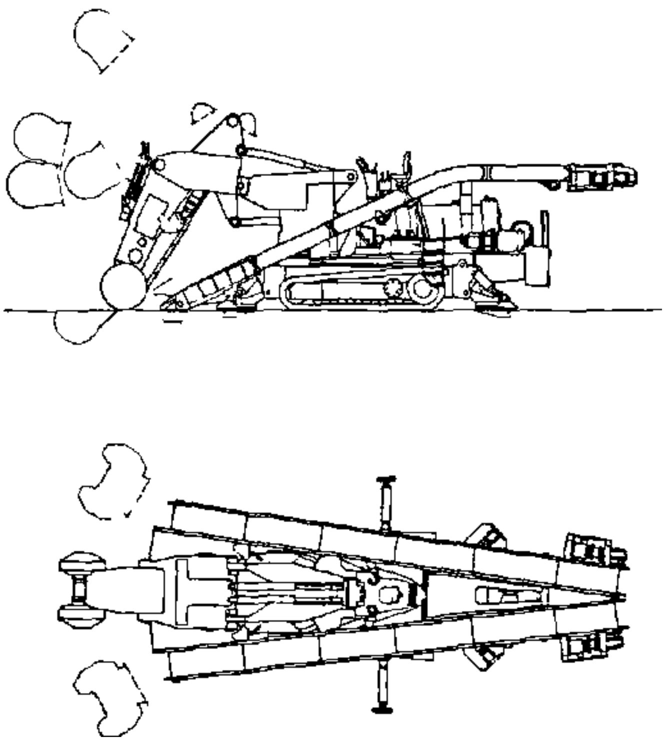


Figure 13. Tunnelling machine WAV 178

Parallel to this development, civil engineering tunnelling required large, powerful sectional cutting machines which, following forepoling at the crown of high tunnels are capable of excavating the remaining section (stope) immediately after completion of the stabilizing work in the calotte, in order to make sure that the support ring can be finished as rapidly as possible.

In this way, the two large sectional cutting machines WAV 178 and WAV 209 were developed, making use of the cutting boom of the WAV 170, stepped up to 300 kW.

With both types, a scraper chain conveyor was arranged underneath the cutting boom in order to evacuate the cut material from the forepoling section of the crown on to the loading shovel.

The WAV 178 (Fig. 13) is capable of cutting a circular cross-section of 8 m diameter from a stationary position making full use of its undercut of 0.9 m. The maximum excavated section amounts to 61 m^2, whereby forepoling of a maximum of 3 m depth can be achieved.

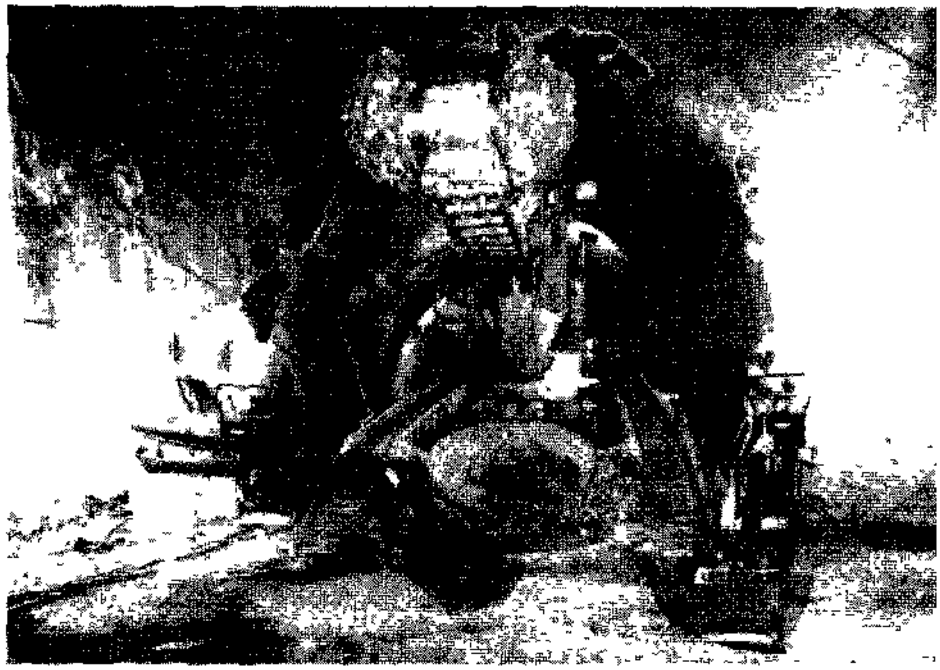


Figure 14. Tunnelling machine WAV 209 in subway construction at Essen.

The WAV 209 (Fig. 14) is currently WESTFALIA LÜNEN'* biggest sectional cutting machine and certainly one of the largest sectional cutting machines in the world. Presented for the first time in 1977, this machine can advance its cutting unit as well as its loading unit relative to the crawler assembly by 1.5 m independenty *of one another.* Thanks *to* its long intermediate boom it *achieves* a cutting diameter of 10 m given an undercut of 1.3 m. The maximum possible excavated cross-section amounts to 116 m^2.

5. FULL FACE BORING MACHINES

Full face tunnel boring is the ultimate goal in civil engineering and mining tunnelling. According to the experience gained up to now high speed of advance can be achieved but the use of full face boring machines demands a suitable long length of drivage to cope with the relatively long installation and dismantling times. The first major triaf of a WESTFALIA Full Face Boring Machine Type TS 3/04 was in driving a gallery in the habour area of Nuremberg in Southern Germany (Fig. 15).

The machine is *so* designed that is *can readily be* adapted to suit specific ground conditions. For application in medium-hard rock the machine is equipped with a cutting head while for stable or soft ground appliation an oscillating cutting tool is used.

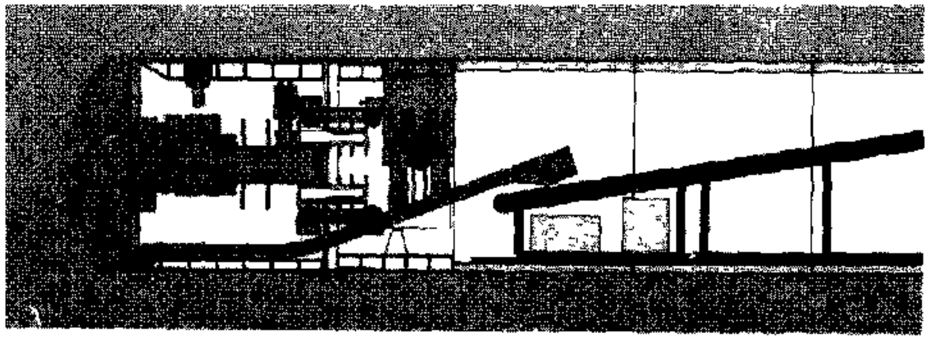


Figure 15. Break through of full face boring machine TS 3/04 after completion of tunnel at Nuremberg;.

The machine dismantles into conveniently sized components, the weight of the heaviest being 3,5 tonnes.

At present the WBM—H 47 is the newest type of these machines. This machine is in use for roadway drivage in Spain (Samuno-Maria colliery). The excavated cross-section amounts to 17,5 m^2, (0 4,7 m) the compressive strength of the material amounts to 20 000 N/cm^2.

Up to now this machine has developed a roadway of 1100 m length with an average advance of 2,20 m/hour.

Tunnelling with sectional cutting machines - and in future also with full face boring machines - offers proven alternatives to conventional roadway drivage. Complete Systems of conventional as well as mechanized technology are available, incorporating all operations necessary for fast, economic and safe drivages in civil engineering and mining tunnelling.