A COST BENEFIT ANALYSIS OF STATE-OF-THE-ART AUTOMATIC INSTALLATION TECHNOLOGIES

WALSH, NOEL PATRICK, EXPORT MANAGER, OPTIMAS GMBH, GERMANY
Address: Eichendorffstrasse 5, D-26160 Bad Zwischenahn, Germany
Tel: +49-171-176-4218 Fax: +49-69-255-77006 Internet: www.optimas.net
E-mail: npwalsh@concreteblockpaving.com

ABSTRACT

The paper presents data on the costs and benefits of using state-of-the-art automatic installation technologies with concrete block paving (CBP). It explains why specialized equipment and careful job planning can maximize the benefits of mechanical installation of CBP. Automatic installation technologies help mimize the life cycle and initial costs of concrete block paving and make the whole idea of CBP more attractive to the end user and considerably more competitive when compared with other pavement options. Considerable developments have taken place in the 1990's most notably huge increases in performance and the spread of mechanical installation to all continents of the world. Machine installation is especially viable on large jobs like port pavements and carparks. Suprising is that machine laying of CBP can even be viable in low labour cost economies and on smaller job sizes of about 40m² or more. This paper shows that the annual job-size threshold is much lower than contemporary wisdom would have us believe. The key to the 21st Century of concrete block paving is using state-of-the-art automatic installation technologies to save as you pave!

1. INTRODUCTION

1.1. „The weakest link in the CBP chain"

The CBP market is growing rapidly worldwide. All members of the concrete block paving (CBP) chain through intensive promotional and technical activity are dedicated to expanding the use of CBP in both established and new market sectors by highlighting their aesthetic, physical and commercial advantages across a wider range of applications.[1]

According to Hagenah, the weakest part of the CBP chain is the critical yet neglected link of the final installation and processing of concrete pavers, slabs and precast kerbs on the job site.[2] A general move towards larger business entities needing „positive results" with more centralized decision making in construction companies, shorter deadlines and the difficulty of finding, training and keeping skilled workers for a „dirty" industry are bringing great changes to the CBP job site. This cost benefit analysis shows when planned and well executed mechanical installation is the best option.

1.2 Background and historical survey

1.2.1 Background

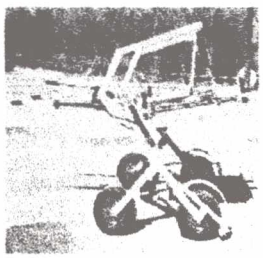
Modern CBP is most developed in Northern Europe and expanding worldwide rapidly. Laying or installing pavers, slabs and kerbs using machines is a new concept frowned upon by some poorly informed "experts". Certainly mechanical laying of CBP worldwide is in its infancy but the recent move by an ever-increasing number of CBP producers and laying contractors to commit to the purchase of mechanised laying machines is a huge step forward. Furthermore, in very developed markets with high volumes of CBP per capita, the old battle of win and lose between producer and contractor is being replaced more by win-win partnering or even customer oriented production in markets where excess capacity or little innovation are characteristics.

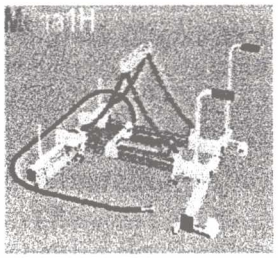
1.2.2 CBP: a change from production to marketing orientation

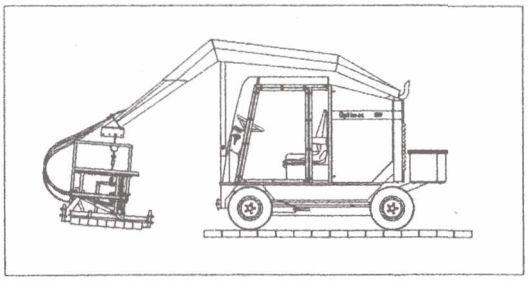
An example of a changing orientation is the increasing number of ISO certified producers worldwide who understand the need for documenting quality and stock tracking within the factory. High quality pavers delivered as the contractor needs them offer major competitive advantages to progressive CBP producers. This new marketing focus is now being taken a step further by progressive producers "partnering" with contractors and key account clients. One key side effect of the increasing popularity of automatic installation machines has been the improvement in the quality of produced and installed pavers [4] – thanks to improvements in production technology and moulds but also to a better understanding of CBP pavements and a greater orientation towards the contractor.

Production problems being solved now are mainly marketing oriented associated with speed, compaction, mixer, colour, size of layer for delivery and pattern oriented questions. Most realize that short term cost objectives in the factory are not more important than the quality of pavers delivered to the job. Examples from the German paving market where pavers are discarded by contractors because of colour inconsistency and blending imperfections demonstrate the changing balance of power in the CBP market. Problems associated with machine laying like patchiness of colours – checkerboard effect – are influenced greatly by cement type and colour consistency. Such problems can be solved if the correct technology and materials were used.[2]

The author believes all CBP producers have to encourage or even force their contractors or even their own contracting division into investing in the latest technology. This paper gives data of interest to decision makers who are considering investing in machinery in the future.







1.2.3 Modern day situation on CBP job sites

Admittedly, machine laid block paving has been available worldwide for years, but to date success in some countries has been patchy. This is mainly due to the unwillingness of the producer to supply ready-to-install units and an inherent instability of the block laying companies. In many markets they are low capital companies, reluctant or unable to fund the cost of the drive-on laying machines, and who frequently go into liquidation – they are often sub-contractors on the job site and are often left unpaid after the job. Early on in a newly developing CBP market labour is often cheap and laying contractors can give a lower price for hand lay block paving (when compared to machine lay option) even though the costs are higher when laying by hand.[1] How can we reduce the costs of laying without investing in expensive equipment?

As an initial step, people turn to the CBP hand trolley system – being used most notably in Africa and China in preference to pure hand laying. With the increasing size of production plant (top of the range plants can manufacture approx. 1.5m² of CBP per cycle) and the use of various larger shaped pavers based on L, T or X profiles – half boards for laying trolley's are too expensive and impractical to deliver and the limitations on weight lifting due to repetitive strain injuries means that these trolleys "do not provide a satisfactory alternative to powered machines".[3]

As a second step, many hope that the use of freely available small or large excavators with mechancial or even hydraulic clamps fitted can offer a noticeable improvement in capacity compared with hand laying. At the same time the working environment could be improved. Due to qualtiy of work and the displacement that occurs , the cost of rig and the danger of driving over uncompacted surfaces [4] and the fact that it is much less efficient than dedicated powered machines[3], such methods are not very viable.

Considerable developments with regard to dedicated laying machines have taken place: better quality finished pavements, machine operation has been simplified to accomodate different paver shapes and different production layer sizes, machines function automatically, speed and weight lifting capacity has more than doubled and more and more pavers are produced only for machine laying even where labour costs are low.

1.3 What justifies more laying technology on CBP job sites?

1.3.1 Cost savings to be made by the contractor

The proportion of CBP installed worldwide using dedicated machines will grow due to many factors, among them being the necessity for better quality and more uniform finished pavements required by architects and clients. More and more the question is becoming: when is machine laying preferable to hand laying?

The more technology used on the job site the lower the cost of the finished pavement.[1][4] Better quality installation methods and the use of more technology on the job site result in more accurate and cheaper laying and a lower cost of the finished pavement – many believe that more technology results in a higher cost of the finished pavement - this results from a misunderstanding of job costing and the question of the investment in the equipment.

Investments in machines are relatively low risk for small companies with good support from the paver producer. Viewed over the life of the investment and taking into account all the benefits, such investments in machines are often the most sensible and cost effective.

Table 1 Machine Feasibility

			(R10= € 1.48	= US $ 1.48)
Paving Machine				
Purchase Price	R 250000,00			
Operating Costs				
Monthly Installment	R 8552,63	(Financed over	3 yrs)	
Driver	R 2500,00			
Assistent	R 1500,00			
Diesel	R 2090,00			
Maintenance	R 1000,00			
Total	R 15642,63			
Monthly Capacity		Min	Max	
Hourly Production m²		70	90	
Hours in day		8	9,5	
Days in Month		22	26	
Monthly Capacity		12320	22230	
Cost per m²		R 1,27	R 0,70	
Average cost per m²				R 0,99
Fixed Costs				
6 m³ tipper	R 3496,00			
Site Agent	R 5000,00			
Finishing Crew	R 6000,00			
	R 14496,00			
Average cost (17275 m²)				R 0,84
Screed				
Purchase Price	R 50000,00			
Operating Costs				
Monthly Installment	R 1710,53	(Financed over	3 yrs.)	
Driver	R 2500,00			
Assistent	R 1500,00			
Diesel	R 1100,00			
Maintenance	R 1000,00			
Total	R 7810,53			
Monthly Capacity		Min	Max	
Hourly Production in m²		70	90	
Hours in day		8	9,5	
Days in Month		22	26	
Monthly Capacity		12320	22230	
Cost per m²		R 0,63	R 0,35	
Average cost per m²				R 0,49
Average Total Cost m2				**R 2,32**
Average monthly m²	17275		**Sales Price**	**Monthly Profit**
			6	63.598,33
			5.5	54.960,83
			5	46.323,33

Table 1 is an investment appraisal based on the „South African costs and benefits". Even at a low annual output of 5.000m² the cost for mechanical installation has been shown to be much lower than manual installation.[5] Such investments should be supported directly (purchase/rent out) and indirectly (lease programs/finacing facilities) by the paver producer.

1.3.2 Cost savings to be made by the client: Mechanical laying and life cycle costs

Who is interested in life cycle costs? Based on the total UK market figures (reported as 20m m² per annum in 1998), with the domestic market, i.e. driveways, paths and patios, representing some 40 % of the total – about 60% of the CBP market can be influenced by life cycle costs.[1] The aesthetic considerations, cost of any reinstatements works, plus the CBP life of in excess of 25 years, are only sometimes enough to convince architects, engineers and ultimate clients that CBP must be preferred to other surfacing materials.

The UK association of paver producers called INTERPAVE commissioned a report by quantity surveyors named E. C. Harris titled "External pavings – a comparative cost study for Interpave". This comparative cost study compared CBP against other types of surfacing materials based on actual costings from completed projects. Allowing for maintenance etc. the report concluded that over a 25 year lifespan CBP is only 0.16 % more expensive than tarmacadam (asphalt). This whole life costing survey also covered the option of mechanical laid CBP and showed that machine laying of pavers brought the initial installed costs of CBP and asphalt much closer together. It proved that if a machine laying rate of 500 m² per day is achieved then asphalt is only 5% cheaper than CBP based on initial costs. Importantly, this differential reduces as the number of square metres of CBP installed (laid) per day increases. [1] Clearly, high performing dedicated laying machines can reduce the initial installed costs of CBP substantially. The next section evaluates the available methods.

2. Methods and technology for installing pavers

2.1 Classifications of methods and technology

The author sees 3 general classifications for installation methods according to the type of technology used: low, medium and high technology. This paper will look at pavers (2.2) in detail and indicate as an overview the methods available for slabs and kerbs (2.3) separately.

2.2 Methods and technology for pavers installation

2.2.1 Low-tech

Laying pavers by hand necessitates some technology to make it more efficient.[5] An hydraulic transport cart allows the mechanisation of laying paver patterns with colours and detailed designs not delivered by the paving factory or where access is limited due to width of area. The hydraulic cart replaces up to 5 manual carts.

The table below has been compiled based on reports from existing customers experiences worldwide gathered over the last 6 years since April 1994. It is indicative in nature and compares average laying rates by hand and results achieved by the same laborers after training and proficiency in operating the laying machines. These averaged results depend on

many factors such as skill, proficiency, climate, type of paving stone, job site size and layout, palletisation, method of delivery to, positioning on job site, etc.

Under optimum circumstances, automatic laying machines are capable of achieving up to 4 laying cycles per minute which would result in maximum capacity of 240 cycles per hour (see table below). The existing maximum cycle capacity of the latest automatic machine is 1.7424m² per layer - this is based on a layer size of 72 rectangular pavers 22cmx11cmx8cm (where WxLxH) in size giving dimensions of 132x132cm = 1.7424m². Such large layer sizes are delivered by MBI in Belgium or RBR in Denmark. For example, a layer size of 1.32m x 1.32m = 1.742m² with certain shapes at 2 cycles per minute would give a productivity of approx. 209 m² per hour. Certain pavers and larger layer sizes allow these productivity rates to be achieved under optimum circumstances. Many job sites do not allow these figures to be reached as averages due to less than perfect job site organisation, too many coffee-breaks and inappropriate payment methods and layer size etc.

Table 2 Productivity Comparsion: manual vs. machine:

Manual rates : In m²/hour/person	**Machine rates**: 1cycle = 1.74m² machine / hour with 2 operators	**Machine rates**: 1cycle = 1.74m² Shows m² per person
1.0	30 m²	15 m²
1.5	60 m²	30 m²
2.0	90 m²	45 m²
2.5	120 m²	60 m²
3.0	150 m²	75 m²
3.5	180 m²	90 m²
4.0	210 m²	105 m²
4.5	240 m²	120 m²

An example of a recent project from the Middle East illustrates the real costs of manual installation even where (immigrant) labour costs are very low. Total area and labor cost/hour can be used to calculate the potential savings in labor costs for a project and evaluate if the necessary investment in machines can be justified.

Job size in total: 200.000m² - 35.000m² were hand installed in 28 days at a rate of 12m²/man/day. Daily average was 1200m² per day using approx. 100 laborers. Labour costs were calculated at UAE DHS 60/day (i.e. US $ 15/man/day). Average labour cost was US $ 1.25 per m². Manual paver carts were used.

2.2.2 Medium-tech

2.2.2.1 Simple scenario

Let us take the same project quoted above from the Middle East. Based on past experience the contractor was convinced machine laying would result in a better more uniform and consistently high quality finish – see quotation. Laying pavers using a specialized paver installation machine with single coloured or nuanced coloured pavers produced in factory moulds implies a huge increase in the productivity of the associated labourers and operators.

„when laying by hand it is difficult to maintain exact joint widths because two persons do not lay blocks exactly the same way. Some persons lay loose and others tight...difficult to keep directions in the pavement under control.... bad tolerances

on blocks with hand laying...well planned mechanical laying gives better quality."[4]

The contractor needed 200 laborers plus 10 supervisors (at an average cost of 100$ per man per day) to achieve 2.400m² per day by hand and to make sure that speed and quality requirements were satisfied for the remainder of the project. Total labor costs per day would be (200xUS$15+10xUS$100) US$4000.

The remainder of the contract approx. 165.000m² was installed using 3 Optimas Comfort machines at an average rate of 2.400m² per day using 36 of the a.m. laborers plus 2 supervisors trained on site. Total labor costs per day were (36xUS$15+2xUS$200) US$ 940. Total labor costs saved by using automatic laying machines was US $ 210.375. Total investment in automatic laying machines and other ancillary equipment plus training and transport was approx. US $ 114.000. Total cost reduction was calculated at US 96.375 for the remainder of this project (or approx. US $ 0.58 per m²). However, if the contractor had started this project using automatic laying machines he would have saved an additional US $ 44.624 – in effect the contractor was losing money left, right and centre. These savings were possible because the pavers installed were delivered in the final pattern ready for machine installation. An added incentive was that the contractor expected to be able to use the equipment on other smaller jobs in the future. For future projects his costs per m² were reduced significantly and his competitiveness improved.

2.2.2.2 Complex scenario – rectangular pavers in herringbone

If the pavers were **not** ready for machine installation – produced and palletised in a pattern which is not the same as the required final laying pattern e.g. herringbone pattern. Based on the above example, the costs of manually rearranging the pavers into the required final laying pattern could also be absorbed by the contractor and the use of automatic installation machines still justified. Laying the paving stones by hand resulted in rates of 12m² per man per day. Rearranging paving stones by hand using a simple conveyor belt device and two (2) packing tables (finished pattern is assembled on these tables) is much quicker due to the simplicity of a conveyor belt situation implying less movement and down time due to mistakes. Approx. 16 workers extra per machine would be necessary rearrange 800m² per day at a rate of 50m² per day. Extra labor costs (16xUS $ 15) of US $ 240 per machine per day would result. For 3 machines total extra labor costs would be US$ 720 per day.

The remainder of the contract approx. 165.000m² was installed using 3 Optimas installation machines at an average rate of 2.400m² per day using 36 of the a.m. laborers plus 2 supervisors trained on site. Total labor costs (laying = 36xUS$15+2xUS$200 = US $ 940 per day) + (rearranging = 48xUS$15 = US$ 720 per day) US$ 1660 per day. Total labor costs saved (68.75xUS$ 2340) by using automatic laying machines including costs of rearranging the pavers by hand was US $ 160.875. Total investment in laying machines and other ancillary equipment plus training and transport and rearranging tables and conveyor equipment would be approx. US $ 126.000. In the complex scenario total cost reduction would be US 34.875 for the remainder of this project (or approx. US $ 0.21 per m²).

2.2.2.3 Simple scenario – shaped pavers ready for machine installation

For example, L pavers from the UNI Group, T pavers from SF Kooperation, X pavers from Xenex, Super pavers from Gopfert Licensing or other special pavers are always ready for machine installation – they are necessarily produced and palletised in the required final laying pattern. These paver systems are ideal for machine installation and engineered

pavements. Ready to install paver layers in the final laying pattern allow dedicated machines to maximize the advantages of automation and mechanisation.

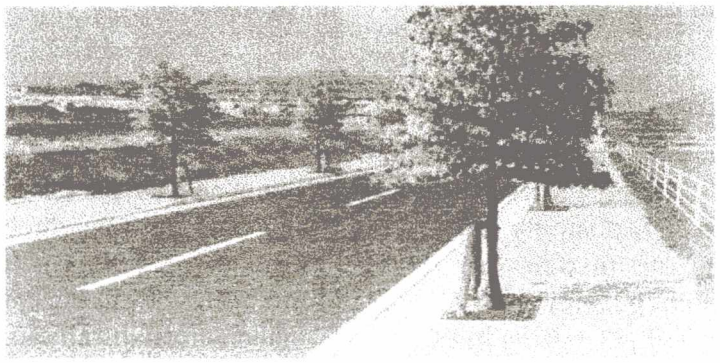
2.2.2.4 Complex scenario – using shaped pavers

What if the shaped pavers were not ready for machine installation – produced on a small board or block machine in the factory at approx. 0.5m² per layer. In competitive markets, rearranging the pavers into the required final laying pattern could be done by the producer palletizing two production boards into a „final ready for delivery layer" – layer size is influenced by internal production facilities and which paver shape choosen.

For example, Lintho (a professional CBP laying contractor from Norway) used layer sizes of approx. 0.6m² and a team of 3 men – one operating the laying machine, the second directing the clamp and the third supplying pallets for the paving front, removing packing and clearing the empty pallets. His well organized team normally lays 500-600m² per day by machine.[4] Having recently purchased the latest technology for the installation of CBP using a layer size of 1.1m² his team now installs an average of 150m² per hour per machine – up to 1000m² per day of finished pavement using 3 workers per laying machine.

2.2.3 High-tech

Laying pavers in complex patterns using multiple coloured pavers (e.g. 25% red, 15% yellow, 10% black and 50% brown) using a specialized paver installation machine implies more packaging (commissioning) technology and a significant increase in productivity. This technology can be used to combine different paver sizes and shapes produced in seperate factory moulds and to avoid colour patchiness by mixing pavers.



A good example of such a system was introduced at Pave Israel 1996 called the Imazu Paver Laying System. The components relating to palletisation or commissioning relate to the factory processes which are conducted off-line.

The Imazu arranging device allows the combination of different clours and shapes into different laying patterns in layer size of up to 1.14 m² (unit area for mechanical laying).[7]

Alternative devices are being developed which lower the cost of such equipment and making it more flexible. Most use cheaper labour, a conveyor system and palletisation tables.

3. Consideration of the state-of-the-art automatic installation technologies

Various technology could be used ranging from manual methods to the use of automatic installation machines/systems whereby maximum productivity could be reached. Let us compare automatic laying machines with hand laying at various selected labour rates and various productivity rates.

Table 3 Costs savings

Area:	**300 m²**	**Manual/Hand**	
Labor Cost:	**20 €/US $**	**2 m²/h**	**Machine 30m²/h i.e. per Person 15m²/h**
Hours needed:		**150,00 h**	**20,00 h**
Labor Costs saved:		**130,00 h x 2600,00 €/US $**	**20 €/US $**
Area:	**3000 m²**	**Manual/Hand**	
Labor Cost:	**20 €/US $**	**2 m²/h**	**Machine 60m²/h ie. per Person 30m²/h**
Hours needed:		**1500,00 h**	**100,00 h**
Labor Costs saved:		**1400,00 h x 28000,00 €/US $**	**20 €/US $**

The above table demonstrates that hand installed CBP is slow and expensive in comparison to machine installed CBP. Individual markets and regions may experience very different market conditions and labor costs than that given in the example.

In accordance with the ideas developed by Hagenah [1] the following recommendations regarding machine laying of CBP should be considered by producers:
1. Appropriate delivery for mechanical installation is a necessity to maximize benefits
2. No limitation of the variety of design by using different shapes and colour blends etc.
3. The Paver Producer must supply tailor-made laying units [8] manufactured according to the laying pattern, colour mixture and mixture of the stone sizes (including edges) and divided into corresponding laying units and packed in a special forming station.[7]
4. Pre-fabrication of CBP pavements in the factory – mechanical installation on site
The producer will earn more money for the extra work of providing "prefabricated concrete block paving pavements" and the producer/contractor will install the pavers quicker with a higher more consistent quality on the job site.

Within the above scenario, the training of operators of automatic installation technologies will become more and more important – Optimas has a 500m² training facility and conducts classes for operators and owners of laying machines so necessary experience and know-how can be passed on to customers. The proficiency and productivity of operators and laying machines is influenced by many factors.[4] For example, it is important that the machines are constantly laying at maximum cycle time and not carrying clusters over long distance.[3]

4. Conclusions & recommedations

Due to the importance of life cycle costs and the potential initial cost reductions achieveable the author believes that machine installed CBP has become the accepted method in most „engineered applications" worldwide. CBP often has a higher initial capital cost of construction of a pavement when compared with other pavement systems like asphalt. Hence, the CBP industry must find ways of minizing or reducing initial capital costs (all costs to construct the pavement structure) and positively influence life cycle costs comparisons.[6] This paper presented proof that automatic installation technologies can make a considerable contribution in reducing initial costs significantly.[1]

Automatic laying machines are being used in low labour cost countries like Nigeria, China, India and Thailand. Where CBP is not so well established (but the concept is no longer new) contractor and producer relationships are often adversarial. In some well developed markets, a well equipped contractor base directly controlled or supported by a CBP producer with access to expert opinion and consultants is the norm. Machine installed CBP will continue to develop because of the potential applications in industrial, residential, urban areas, low speed roads, hard shoulders on motorways etc. and the need for producers to sell the lower cost finished pavements and not individual pavers.

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