HI-TEC SOLUTIONS TO MOLDING PROBLEMS ENCOUNTERED IN THE MANUFACTURE OF "ZERO SLUMP" CONCRETE PRODUCTS

Josef Ott and Bernd A. Andreas
Rampf Molds Industries Inc.
90 Western Maryland Parkway
Hagerstown, MD 21740 USA
Phone: (301) 791-6880, Fax: (301) 791-0327
E-mail: sales @rampf.com

SUMMARY

This paper provides an overview of the latest international trends pertaining to the manufacture of concrete hardscaping products. It describes the problems manufacturers can expect to face in the pursuit of these potentially very lucrative product trends. It also shows readily available detailed technical solutions are readily available for solving these problems. Finally, it offers an outlook on the trends of tomorrow and preparations for producers in meeting oncoming challenges.

1. INTRODUCTION

1.1. History of Zero Slump Concrete

The modern history of "Zero Slump Concrete Products" is about 60 years old. It essentially started after World War II when building materials were scarce and trading at a premium. What began as a manual operation, i.e. filling a wooden or metal form with a semi-dry concrete mix, tamping it firmly and demolding it to let it cure on wooden boards, became -over time- increasingly mechanized and automated. Today, multimillion dollar plants automatically meter and mix the individual concrete components, color them, pour them into the mold, compact, demold and package the product in a matter of minutes, not hours as used to be the case.

Although the capital requirements to build and operate such a plant have substantially risen over the last twenty years, the product unit cost has drastically decreased, putting the finished product in the consumer's hands at an affordable price which - besides the marketing efforts of the producers - is accounting for the dramatic increase in the use of the product itself in North America and on a worldwide basis.

1.2. Recent trends and Market Requirements

With increased exposure to and awareness of the product also comes heightened demand for

- better product quality
- greater variety in shapes, looks and color
- products that closely resemble natural stone

to the extent that the products themselves become more complex and, increasingly, subject to fashionable trends that change ever faster.

It is the mold maker's task to ensure that, all other things being equal, in the 8-20 seconds that it takes to shape, compact and demold the product. The mold will do its job not only once but literally tens of thousands of times without noticeable deterioration until it finally gives up its ghost. Apart from this, he can do several things, such as providing enhancements to the mold or to be used separately from the mold to help the industrial producer better address the above mentioned requirements of the buying public. What these enhancements are and how they help to provide better product quality, lower cost and more choices to pick from will be discussed in our presentation that follows:

2. SOLUTIONS TO MOLD LONGEVITY

To increase mold life we need to know what causes the molds to unduly wear, all other things being equal. Below are the factors which reduce the mold life.

- Long main vibration time
- High head pressure during final compaction
- Hard aggregate
- Crushed aggregate with sharp edges
- Molds not properly hardened
- Poor mold alignment
- Poor mold maintenance
- Poor machine maintenance

The life of a mold can be extended significantly by using common sense. Looking at the short list above it is quite obvious that there are a couple of key elements which influence the mold life. Keep the main vibration short and the head pressure low. Select mold friendly aggregate which is round, not split and not too hard. Also, the maintenance on the mold and machine will influence the mold life.

2.1. Reduced Cycle Costs

Cycle cost calculation is not merely the cost of the mold divided against cycles run. One must consider the waste which is being produced during setup and inefficiencies while running a given mold.

2.1.1. Materials

The materials which we are using today in the molds have come from the machinery and defense industries. Presently they are all made of steel. The requirements of the mold steel are broad. It needs to be hard, abrasion resistant, tough, resilient to shock, weld able, forgeable, bendable and inexpensive. Currently there is no steel readily available which has all those characteristics. Most of the steels may have 3 or 4 of the above features. Depending on the primary requirements the steel which fits best the application is chosen.

2.1.2. Hardening processes

Most steel types that are readily available and affordable from a price / value point of view are by themselves not hard enough to withstand the rigors of daily use for a long enough time. This is why in many cases additional hardness is induced into the steel by exogenous sources. Currently there are three hardening processes used to manufacture molds for Zero Slump Concrete products. They are case hardening, nitriding, and flame hardening. All of those have unique advantages which make it viable option for the future. Table 1 summarizes these processes.

Table 1. Steel Hardening Processes for molds

	Advantages	Disadvantages
Case hardening	Hardness 63HRC and a case depth of about 1.5mm The best hardening process known at this time.	Large complex shapes are difficult to harden. Weldments cannot be hardened. Expensive process
Nitriding	Hardness 70HRC Complex shapes can be hardened Weldments can be hardened Excellent demolding properties	Hardness depth 0.8mm Expensive material
Flame hardening	59HRC and a case depth of about 1.3mm Complex shapes can be hardened	Difficult to machine

2.1.3. Alignment pins
Definition:
The alignment pin brings the mold bottom into position just before the shoes of the tamper head penetrate the mold bottom.

Applications:
Paver machines with a floating head.

Advantages:
- Reduced shoe wear ("crisper" paver chamfer detail)
- Reduced plunger failure
- Improved mold life

Operation:
During the paver manufacturing process the shoes penetrate the mold bottom for final compaction. If the tamper head is not aligned properly then it will hit the lead in chamfer of the mold bottom or the mold bottom webs. This collision will eventually damage the shoes, the mold bottom, the tamper head structure and even the paver machine. The alignment pin system will not allow a collision between tamper head and mold bottom. The mold bottom and the tamper head is aligned just before they meet. As soon as the shoes are in the cavities the guiding pin system releases to allow an unrestricted vibration to the mold bottom.

Installation:
The operator does not have to do anything different from the standard mold.

2.1.4. Flexible Plungers
Definition
The flexible plunger has been developed to reduce stress failures of plunger tubing by reducing the stiffness within the plunger design. This new plunger design acts more like a spring then a rigid element between back up and head top plate.

Applications:
Any mold which has a history of plunger failure.

Advantages:

- Less down time
- Improved surface finish (troweling effect)

Operation:
Typically the plunger is rectangular steel tubing which is part of the tamper head structure. During the engagement of the shoe into the mold bottom a substantial amount of stress may be exerted on the weld which connects the tubing with the head superstructure. This stress may be prolonged or increased if the vibrators of the paver machine generate not only vertical but also horizontal forces. To minimize the stress on the weld, a plunger was developed, which acts more like a spring and absorbs the stress peaks.

Installation:
The operator does not have to do anything different from the standard mold.

2.2 Product Quality

"Product Quality" has two aspects. First the visual / aesthetic quality. This is how the product presents itself to the potential user. The second one is the inherent product quality, such as density, compressive strength, being dimensionally correct etc. The quality of today's concrete products has significantly improved over the past 20 years. The equipment which is producing these products is more sophisticated. Currently, we still have a density variance of about 8-10% on any given layer of products as it comes out of the standard mold.

2.2.1 Height Control System
Definition:
The height control is a device which is integrated in the mold to produce a product with consistent elevation of ±1mm.

Applications:
Product which requires a tight height tolerance. For example the classic 150 mm and 200 mm tall dry stack retaining wall products, building blocks. Secondary operations like grinding or calibrating may in many instances omitted if the above height control device is being used to manufacture the concrete product.

Advantages:

- All the stones on the pallet will have the proper product height (±1mm).
- Product height will be preset by the mold manufacturer (no adjustment needed by the machine operator)
- Manufacturing pallet thickness variations are being compensated with the height control system
- Minor fill variation are being compensated with a extended or shortened main vibration cycle
- Visual feedback on height pin allows the operator to make minor adjustments to fill.
- Reduce waste up to 90%
- Will not allow exceed preset maximum main vibration time.

Operation:
The tamper head has a moveable pin in all four corners of the head top plate. These 4 pins are stopping the tamper head from further penetrating the mold once it has reached the product height. The tamper

head pins are contacting pins in the mold bottom. The mold bottom pins are encased in rubber buffers to isolate the vibration from the height pin system. This allows the mold bottom to move freely up and down during the final compaction phase.

- At the beginning of the manufacturing cycle the four pins in the tamper head are locked into position.
- After the mold filling cycle is completed the tamper head lowers and the final compaction is started.
- Compressed air is being forced through the center of the height pins in the tamper head onto the bearing surface of the mold bottom.
- The air stream has two functions; it cleans the mold bottom contact area and by monitoring the back pressure at all four pins the Height Control PLC "knows" when it has made height. As soon as a pin "makes height" the appropriate light comes on. This feedback system allows the operator see in what order the pins made height. He now can make the decision to change or not to change the feed of the mold to improve the fill in the next cycle.
- As soon as three out of the four height pins "have made height" the Height Control PLC sends a signal to concrete products machine to stop vibration and demold. The height control operator panel has 4 lights which correspond to the 4 height pins in the mold.

Installation:
The Height Control PLC has three connections. (…one signal cable goes to the Concrete Products machine panel, one cable goes to the tamper head and the third cable is the power cord). The tamper head also needs to have compressed air. The installation and integration of the control can be easily achieved within one 8 hour shift.

2.2.2. Harmonized Mold Vibration
Definition:
The HMV mold has been optimized by reducing mass in the mold bottom and strategically adding polymer concrete pockets to improve the vibration pattern.

Applications:
Paver molds which need to produce a consistent quality throughout the whole manufacturing board.

Advantages:

- Improved vibration signature
- Broader vibration frequency bandwidth (resonance frequency is higher than that of the standard mold)
- Improved filling of mold cavities
- Consistent density throughout the pallet (The optimization of the Harmonized Mold Vibration has produced improvements of about 5 to 7 %.)
- Reduced cull rate
- Improved mold life
- Available for most board machines

Operation:
Strategically located weight reductions are being used to improve the vibration pattern of the HMV mold. The voids are filled with polymer concrete to further improve the vibration performance. The selected geometry also improves the stiffness of the mold bottom. This feature helps to prevent wear.

The mounting brackets are bolted on to the insert. This design prohibits most of the vibration energy to move in to the mounting brackets which means it has to be dissipated in the insert area. Due to the design modifications the resonant frequency has shifted upwards by about 20%. This allows using the upper end of the vibration frequencies of the paver machine.

Installation:
The HMV mold does not require much set up time.

- The vibration amplitude and frequency need to be set up.
- The offset between vibrating table and stabilizer bar must be proper.
- The feed- and main vibration time may need to be reduced.

2.2.3. Oscillator
Definition:
With the oscillator mold, the insert is completely decoupled from the mold frame. This design allows the mold insert to move within its predefined space during vibration without the restriction of a welded or bolted frame.

Applications:
Molds which are difficult to fill during the production cycle. Concrete products which require consistent density from top to bottom like taller lawn edging stones, palisades and units which require a perfect side finish.

Advantages:

- Excellent vibration signature
- Improved finish of sides for landscape edgers
- Improved filling of mold cavities
- Consistent density throughout the pallet
- Reduced cull rate
- Less vibration energy required
- Substantially improved mold life (up to 40%)
- Available for all board machines

Operation:
The oscillator mold makes use of the higher frequencies of the paver machine. Not the amplitude should be increased but the frequency of the vibration. In a lot of cases is the mold insert weighs between 25-35% of the total mold bottom weight. This means that the frame weighs about 65-75% of the mold bottom. This is a lot of dead mass which is being agitated by the paver machine. By decoupling the insert from the mold bottom, a substantially higher frequency develops in the mold insert. This then leads to a denser product.

Installation:
The Oscillator mold does not require undue set up time; it actually is extremely simple to set up. Just follow standard housekeeping rules.

- The vibration amplitude and frequency need to be set up
- The offset between vibrating table and stabilizer bar must be proper.
- The feed- and main vibration time may need to be reduced.

2.2.4. Laser Height Measuring System
Definition:
The laser height measuring system consists out of two or three stationary lasers behind the concrete products machine. Each laser measures a row of concrete products in feed box direction with an accuracy of 0.1mm.

Applications:
Any concrete product which is height sensitive.

Advantages:
- Immediate feedback about product height
- Out of height spec, product are identified immediately
- All of the height measurements data can be exported
- Statistical analysis possible

Operation:
The Laser measuring system is typically installed behind the machine. The structure straddles the pallet conveyor system about 400mm above the pallet. The operator decides where to measure the concrete products on the manufacturing pallet. As the product travels underneath the laser it reads the elevation of the pallet and then the elevation of the paver. The software has numerous features to which will give the operator and quality manager myriad of useful information. It can for instance trigger the dump station if the product does not meet the height requirements. The operator can set up an infinite number of custom recipes. In those recipes the upper and lower limits for the product height are defined, actions like trigger a pallet dump, activate an audio or visual signal, stop concrete products machine can come into play if the limits are exceeded.

Installation:
The unit is being installed within a matter of hours. The laser requires virtually zero maintenance.

2.2.5 Table Meister
Definition:
The Table Meister is a vibration table verification and setup tool.

Applications:
Any concrete products machine which has a vibrating table with stabilizer bars.

Advantages:
- Accurate offset measurement between vibration table and stabilizer bars.
- Large easy to read digital readout with absolute value.
- Reduced vibration table setup time.
- Extremely accurate table setup
- Even vibration throughout the whole manufacturing area (more consistent product quality).

Operation:
The Table Meister is two tools in one. It measures the relative distance between the vibrating table and the stabilizer bars and also the “twist” in the vibrating table and or stabilizer bars. To measure the elevation of the stabilizer bars relative to the vibration table we need to setup the Table Meister the

same way as the classic straight edge. Instead of using shims to check the clearance we get the distance via digital readout. The "twist" (plainness) of the vibrating table is being detected through the electronic level.

Setup:
The Table Meister is portable. One Table meister can be shared with many plants. All the electronics are supported via built in rechargeable batteries. The electronic level has a non rechargeable battery. The unit is operational after the cable is connected between the Table Meister and the handheld readout.

2.2.6 Feed Equalizer
Definition:
The Feed Equalizer improves the uniform density across the production board.

Applications:
Any mold especially one with large cavities which is difficult to consistently fill properly.

Advantages
- Improves the consistent density across the manufacturing area.
- Difficult products (large format stones) can be manufactured successfully.
- Product quality is higher.
- Low maintenance.

Operation:
The Feed Equalizer has shoes which are mounted on airsprings. During the initial compaction cycle the airsprings are inflated via compressed air. The shoes are applying equal pressure on each cavity. Depending on the degree of fill of each cavity the elevation of the pre compacted product varies. The face mix feedbox is now making up the difference of fill. The airsprings are deflated and the final compaction takes place.

Setup:
An air solenoid needs to be integrated into the PLC of the paver machine. The initial setup and plumbing of the air line can be completed within hours. The Feed Equalizer has one air line which needs to be hooked up. The operation of the mold is completely automatic and does not increase the cycle time of face mix product.

2.3. Emulating Nature
2.3.1. Reverse Engineering
Definition:
Reverse Engineering is being used to duplicate natural stone surfaces in the Zero Slump concrete products environment.

Applications:
Any pavers, retaining wall or curbstone products.

Advantages:
- Natural look.

- Premium price in the market place.

Operation:
The first step is to decide on one or multiple "specimens" which are to be duplicated. A laser scanner creates a digital model of the surface. This model is then being evaluated. Oftentimes it requires extensive editing of the digital model to achieve a surface which is will be suitable for manufacturing of zero slump concrete products. This process requires a high degree of interaction between the concrete products producer and the mold maker. A word of caution: The coarseness of the aggregate used will determine the amount of detail the final product shows.

Setup:
Depending on the degree of surface definition, oftentimes these molds require heated tamper heads and modified brush setups. (The temperature controller can be provided by the mold manufacturer)

3. AN OUTLOOK TO THE FUTURE

Future views might include:

- Other material then steel
- Molds may have integrated vibrators
- Real time vibration analysis
- New tighter way of collaboration this could include plant evaluation / audits
- Molds are viewed as part of a complete manufacturing process not as a isolated manufacturing element

3.1 New Materials

Tomorrow's mold may not consist out of steel entirely. The mold liners could be a tough ceramic, the top of the mold a mat of Kevlar and the mold frame could be constructed out of carbon fiber profiles. The potential advantages are:

- Reduced mold wear
- Stronger mold frame
- Lighter molds (less vibration energy required)
- Shorter lead time to manufacture molds

So far cost has kept the market from accepting any of these new technologies/materials.

3.2 New Bonding techniques

Currently the mold components are being connected via a bolt or weld. In the future we will see components to be secured by cold fusion technologies.

3.3 New vibration techniques

The new vibration technology will have accelerometers embedded in the mold. These units will communicate with the paver machine and be part of the feedback loop. The system will "learn" the vibration characteristics of each mold and regulate the vibration energy accordingly. The challenge so far has been to find a power source which can withstand the 200g acceleration forces which are induced to the molds at times.

3.4 The Holistic view

To improve the manufacturing of Zero Slump Concrete products it is important to look at the whole process. Here some pointers what to look for:

- The foundation of the paver machine must be good.
- The machine frame cannot have any cracks.
- The vibrators in the table must be identical
- The vibrator weights must be set up properly
- The rubber buffers for the vibrating table must be in good condition.
- The vibrating table must have the proper rubber buffers (hardness and count)
- The vibrating table with the wear strips must flat and true.
- The manufacturing board guide system must be in good order.
- The mold bottom needs to be flat and true.
- The mold bottom must have no cracks.
- The guide system for the mold must be in good condition
- The mold bottom hold down system must work as designed.
- The tamper head guide system must be in good order.
- The tamper head must have no cracks.
- The tamper head ram must have the proper rubber buffers (hardness and count)
- The tamper head ram rubber buffers must be in good order.
- The tamper head guiding system must be in good order.
- The head locking device must function properly.
- The hydraulic system must function properly.

If one of the above components is not functioning as designed the quality and consistency of the product may be jeopardized. The problem is that, by and large, individual producers are very reluctant to admit that they might have operational challenges in their organization. Likewise equipment suppliers will typically try to shield occurring problems from public view. One of the solutions to this problem might be to develop an association of certified equipment/plant auditors whose function would be to identify and cure existing problems without attributing public blame. Individually such experts are available. It is up to the industrial partners (i.e. producers and suppliers) to find ways to avail themselves of these resources without falling into the “blame game” trap.