Methodology to evaluate the dispersion of weight, density and strength

How to reduce the standard deviation in the production process of blocks and pavers

The process of producing vibro-pressed concrete goods, or "semi-dry concrete" as it is known in many countries, is very different from the methodology used to obtain products with conventional plastic concrete.
While in plastic concrete the most important parameter that directly affects the quality of the final product is the water-cement ratio (w/c), in vibro-pressed concrete it is the final density of the concrete element after its proper compaction and vibration. This is because the final density of the concrete element is directly related to the degree of compression that the equipment provides to the product and hence its porosity, permeability, strength, absorption, etc.

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We have already seen in the previous article in CPI issue 3/2014 that the behaviour of the strength of concrete with respect to the addition of water manifests itself to a certain degree inversely in each of these types of concrete due to this variation in density.

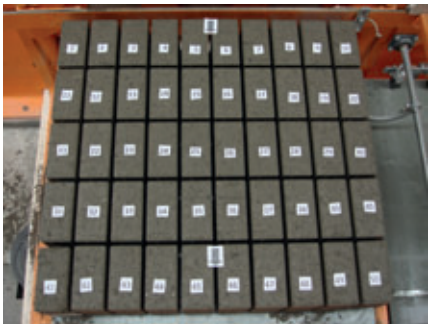
Besides, in several countries such as Brazil, the variation of the resistance values around the mean or standard deviation is used to calculate the parameters and obtain the characteristic resistance of the product. Several other parameters can be used to assess the quality of a vibro-pressed element, such as the best known and most commonly used: compressive strength, tensile strength, water absorption and surface wear. All these parameters are influenced to a very great extent by the density of the concrete or density of the finished element. Certainly there are numerous other factors related to the production process that interfere with the variation of the parameters mentioned above; if changes occur, for example, in the w/c-ratio during the curing process, or in the particle size of the aggregates, the type of cement, the quantity of measured materials at the time of mixing or the efficiency of the additive added, etc., there will certainly be changes in the properties of the concrete, mainly in its compression resistance.

But all these variables together are less frequent than the effect due to the variation in the density of the elements after proper compaction.

The variation in the density of the elements can occur from one batch to the next, for instance caused by a variation of the quantity of water measured. It can also occur from one cycle to another in the same batch, caused by the level of material in the hopper and even in the same cycle, or the same pallet.

When density variation occurs, there will be elements on the same pallet with different levels of compaction: more or less compacted if they are located in the centre and at the ends and rear of the pallet, and all of this caused by differences in filling the cores. Therefore, the control of the density of the elements can be a great help in lowering the standard deviation of the production process and improving the characteristic strength of the whole batch of products.
The establishment of a standard weight of the elements before and after the vibration and compaction process is the method mostly used to achieve this purpose. But more important than controlling the problem is the identification of its origin and, knowing its magnitude and its causes, its elimination. The first step is to know the standard deviation, learning where the most critical elements are on the pallet, meaning those that have a density quite different to the mean on the pallet or in a particular batch average.
Start by taking a photo of the pallet going out of the press and set a sequence to identify the elements, for example, from left to right and back to front, as is illustrated in the next picture.

Afterwards, design and type a spreadsheet in Excel with exactly the configuration of the pieces on the pallet, see example below.



Pallet of pavers in the position left of the machine

	Minimum		Average			Maximum		
	3390		3552			3664		
-5,0%	-3,8%	-2,5%	-1,3%		1,3%	2,5%	3,8%	5,0%
3375	3419	3464	3508		3597	3641	3686	3730
D	C	B	A	<= Class =>	A	B	C	D
Little Compact							Very compact	

Excel spreadsheet with data from the pallet

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Insert a column in the Excel sheet to identify the values which deviate above or below the average according to a range of background colours of cells, as is shown in the example:

At www.doutorbloco.com.br you can find and download an example as an aid to help you design your own and adapt the worksheet to the size of your pallet.

By doing this, you can identify the pieces on the pallet that received a greater or lesser quantity of material in relation to the mean, for which reason those elements have extreme values of weight and density. This will also identify the elements that, becoming very compact, act as a wedge, preventing the shoe compression from providing the proper compression to elements that receive the smallest amount of material. To identify which elements are faulty you can interfere in the process, whether it be the silo conveyor belt system, better distribution of the material in the silo and in the cart, the times of the agitator, the fingers of the spreader, the height of the ruler, or the frequency and amplitude of vibration at different positions of the pallet, so as to better fill those cavities that receive less material and lower cavities which receive those very materials.

Pallet 1				
3580	3508	3502	3445	3390
3588	3588	3490	3486	3398
3602	3585	3580	3499	3440
3650	3595	3565	3545	3490
3645	3608	3570	3554	3498
3661	3625	3588	3568	3500
3664	3618	3580	3580	3472
3659	3605	3591	3576	3477
3640	3601	3576	3535	3414
3636	3594	3555	3502	3406
3632,5	3592,7	3559,7	3529	3448,5
Maximum	3664			
Minimum	3390			
Average	3552			

Excel spreadsheet with color-coded rating

Deviation due to the variation in measured amounts of materials.

When the deviation is caused by a variation in the amounts provided to the mix, this situation is easy to identify because a variation in the resistance occurs with no change in density but a variation in the texture or colour, which means a total change of the appearance of the element.

A very simple way to check the balance is to make a comparison between the total quantities of heavy materials at the end of the day including water (the machine or the control panel usually provides this information) and the total weight of processed product that day. This can be done by multiplying the number of pieces produced by the average paver weight. If the values are not close, it will be necessary to investigate the cause of the difference.

Deviation due to variation of the moisture in the mixture

Another possible factor of the standard deviation is the variation of the moisture in the mixture. If this is the case it is important to use a humidity controller, like Conductive, Hydronix or Hydrostop, which are a few examples of good equipment for this purpose.

If you do not have a humidity controller or if this is out of order, it would be wise to observe the vertical faces of the pavers and to ascertain whether there are any stripes. The other way to determine this is to observe the upper surface of the paver and note whether it exhibits the "orange peel" effect, which confirms that the element has been produced with the right amount of humidity and was correctly compressed. ■