AN EFFECTIVE DRY SAND MANUFACTURING PROCESS FROM JAPAN POTENTIAL TO REPLACE NATURAL SAND ENTIRELY IN CONCRETE

INTRODUCTION

There is little doubt that viable natural sand resources in many areas across the world are running out, either because of extinction or sterilisation of reserves, cost of extraction or transportation, or because of environmental concerns. An additional problem in some areas is the shortage of water for processing.

Against this background, and drastically falling domestic demand for their traditional products, Japanese equipment manufacturers began, around the turn of the millennium, to seek a potential niche to fill in the quarrying market. The only growth area seemed to be in the production of manufactured sand; despite a plummeting overall aggregate requirement, natural sand supplies were dwindling faster than the need for concrete. This led Kotobuki Engineering & Manufacturing Co. Ltd. (Kemco) to devise a process for the manufacture of consistent specification sand, using crushed rock as a feedstock. The resulting system is known as the V7 Sand Manufacturing Plant.

40 t/h PLANT IN JAPAN

MANUFACTURED SAND

Material described as manufactured sand can range from unprocessed quarry dust to, at best, carefully processed fine aggregate specifically designed for use in concrete or other products. It can be gritty, flaky, and full of filler*, or it can be well shaped and graded, assisted perhaps by a fortuitous tendency of the parent rock to produce equidimensional** particles in the right size range. In some instances serious attempts have been made to mimic the characteristics of natural sand using milling machines and sophisticated classification, but this is usually very expensive.

One area in which manufactured sand can score over naturally-occurring material, however, is in consistency – some sand pit products are notoriously variable, leading to many concrete producers routinely increasing cement content to cover all eventualities.

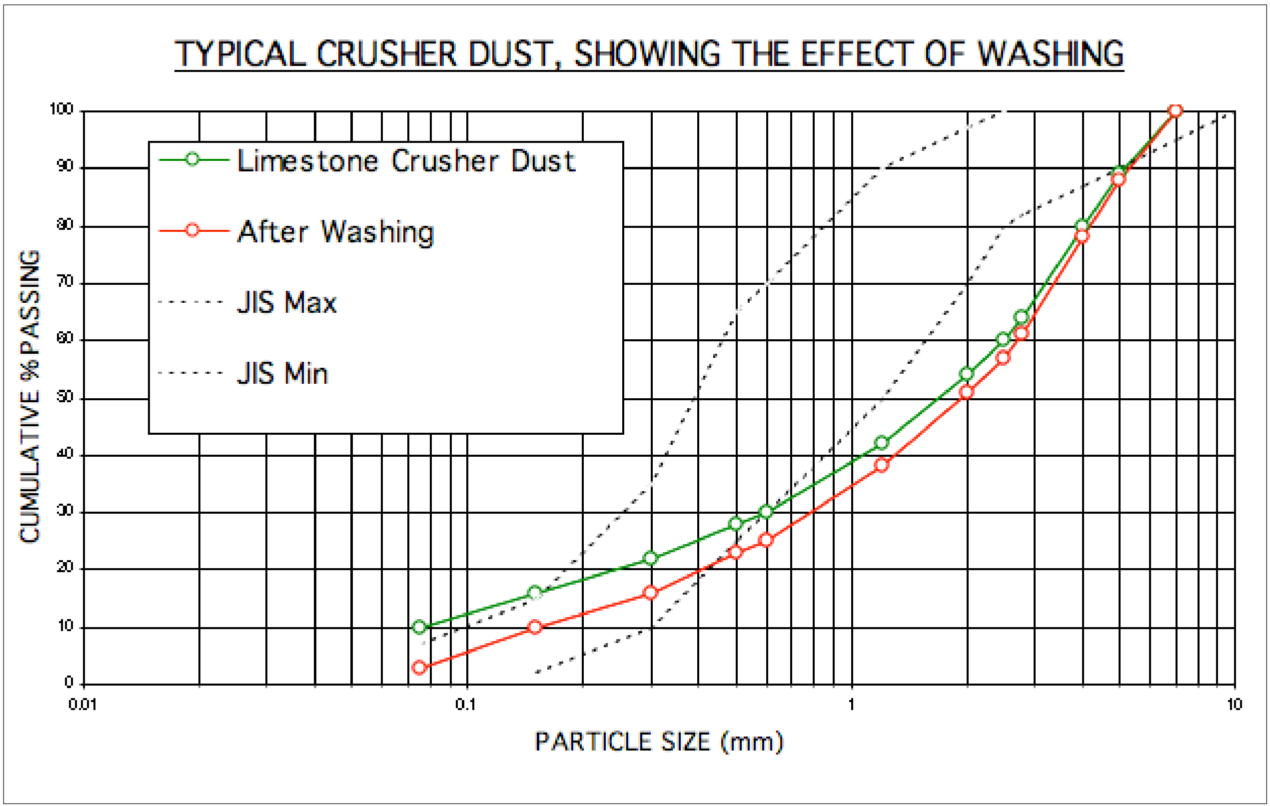
So what is wrong with using crusher dust as fine aggregate in concrete?

It is beyond the scope of this article to go into detail, but the main factors are particle size distribution and particle shape. To generalise, concrete producers need a very specific and consistent gradation in their sand that is not typically satisfied by the fines produced in conventional rock crushing. We usually find that the coarser particles are abundant, there is a shortage of material in the crucial 150μm – 1mm range, and an excess of <63μm or filler.

A good deal of research continues into high filler concrete mixes, but the fact remains that to use (and to sell) crushed rock as sand, it has to look, feel and behave like sand, which means, among other things, controlling the filler content and the particle shape:

Compression crushers - accepted as being the most efficient size reduction equipment, at least in abrasive situations - are not good at producing equidimensional, or sand-like particles, but instead grains are often flaky or elongated, and sharp-edged, leading to increased surface area (which needs more cement/water to coat it), increased voids ratio, and reduced workability in end use. To add to the difficulty, compression crushers are often unable to produce a consistent gradation as their wear parts deteriorate. Impact crushers, particularly of the autogenous VSI type, tend to produce rather better particle shape, with rounded edges, at the expense of additional filler generation. With all conventional crushers, there is a difficult particle size range below 1mm where particles may not be sufficiently abundant to make well graded sand.

Unprocessed crusher dust is therefore usually regarded as only suitable to be incorporated in a blend with natural sand, and only then if it is of good quality, and cheap enough to make the substitution worthwhile. The main impetus behind its use is to dispose of an excess of what would otherwise be a waste product, rather than an attempt to make sand production an integral part of the quarry's product range. In order to improve saleability, many operators have installed washing plants, to remove most of the filler. This does nothing to address the deficiency in the 150μm- 1mm size range, or to reduce the effect of poor particle shape. the chart below shows crusher dust before and after washing. Washing also provides the operator with an additional headache in the form of effluent disposal, which means either a settling pond, or an expensive filter press, and all the associated problems of handling unsaleable waste.



SPECIFICATION FOR SAND PRODUCING PROCESS

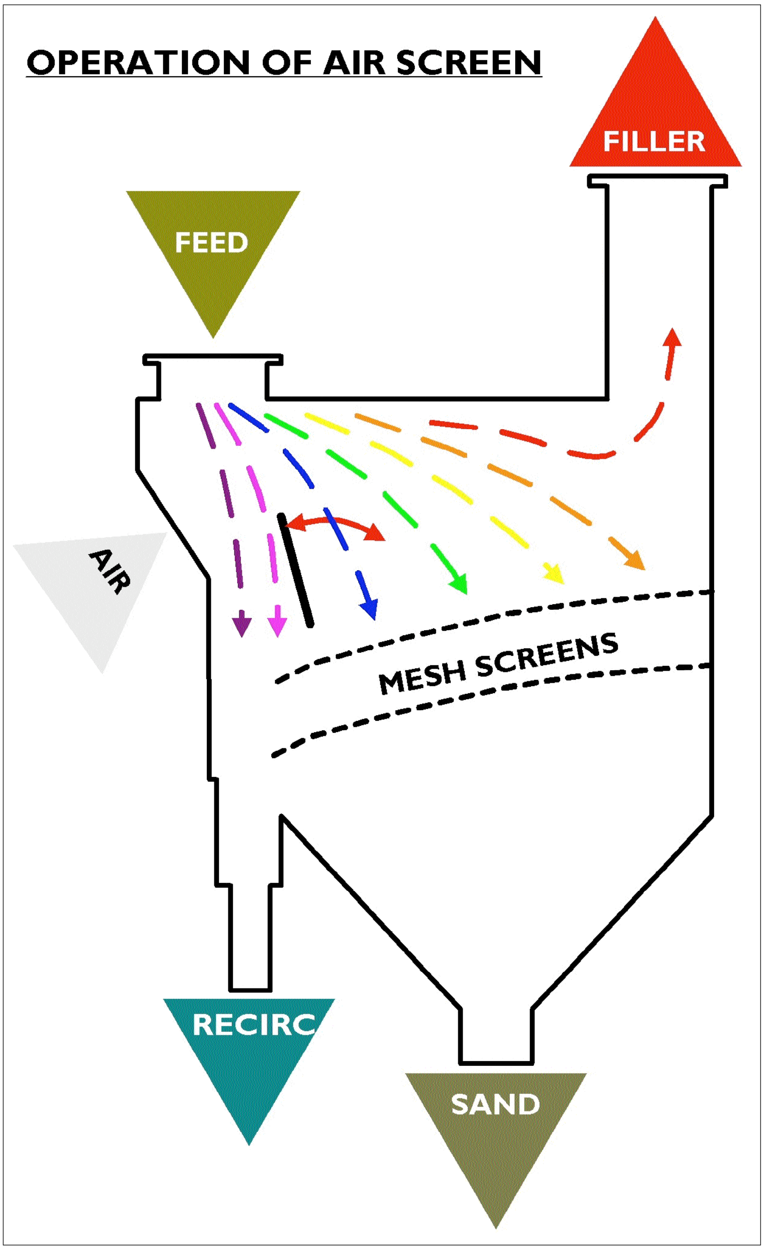
Assuming a starting point of dry crushed rock fines as feed, the designers of the V7 process sought to produce a system that would generate sand conforming to the Japanese specification (broadly similar to the American ASTM C33), with superior particle shape throughout the size range, controlled filler content, and the ability to maintain consistency despite variations in feed. Additional requirements were that the process should be environmentally acceptable, and should not involve water, pumps, and effluent for disposal, and that the space occupied by the plant should be minimised. The process should be automatic, and need minimal maintenance.

They managed to resolve all these issues, invariably being able to bisect the limits of the JIS envelope using a wide variety of feed materials and gradings. The result is that approaching fifty plants have been installed in Japan, many of them repeat orders as the quarries involved have altered their product mix to concentrate on sand production.

THE SOLUTION

The first stage was to develop a crushing machine, known as the US7, able to produce an abundance of the "difficult" sized grains discussed earlier. This was achieved by developing existing autogenous VSI technology, but incorporating a milling function, using tungsten carbide impact members, and a restriction on the crushing chamber outlet, thus forcing the material into a zone of powerful attrition.

In a conventional autogenous VSI, the energy transfer necessary to break already small particles is difficult to attain, and merely increasing the speed, and thus the kinetic energy, of the particles has little effect beyond that of sandblasting extra filler into existence. This process does improve particle shape by breaking off or abrading protuberances, but for advantageous size reduction, impact of particles against some kind of relatively immovable object is necessary.



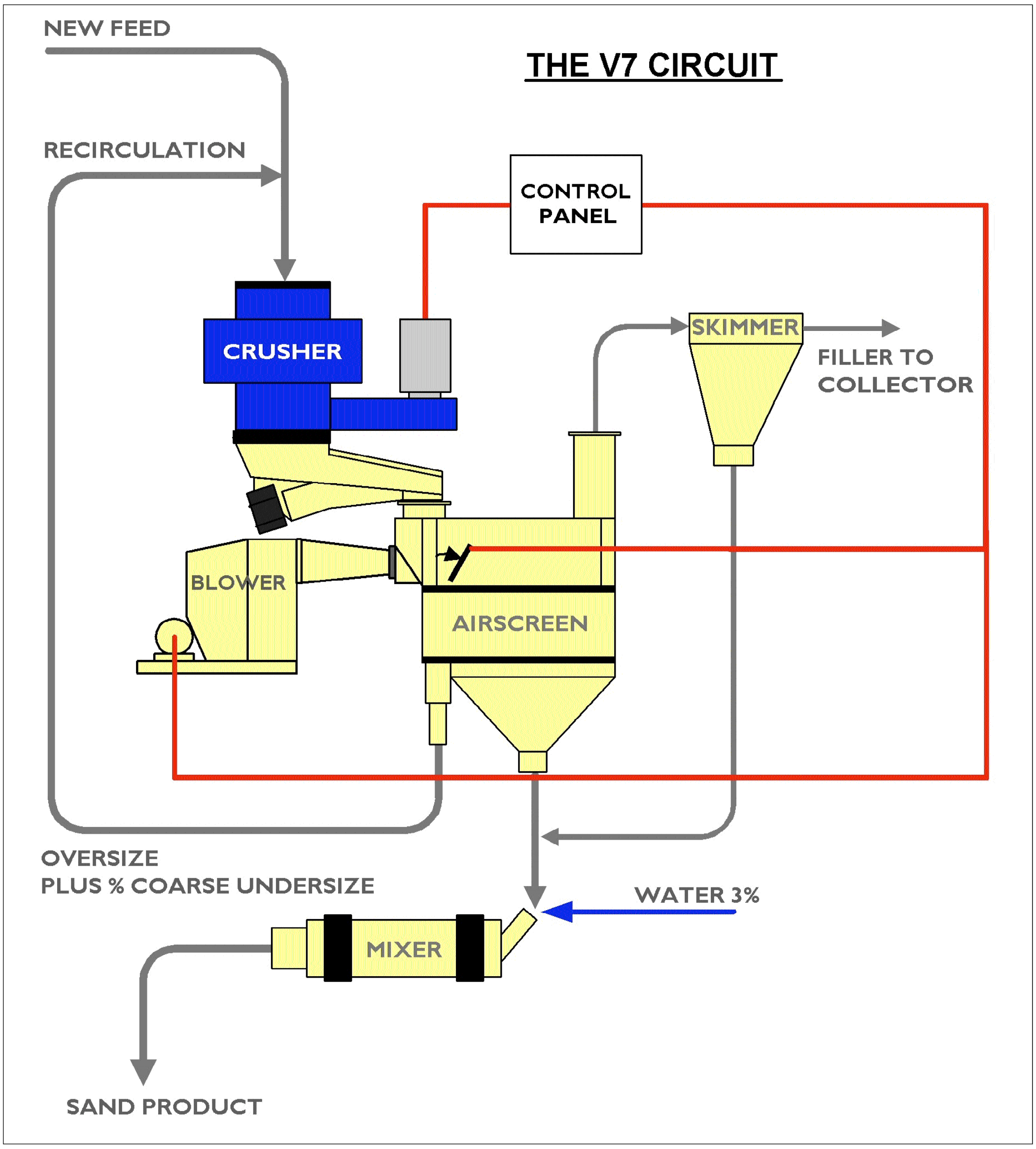
In the US7, when particles collide with the tungsten carbide hammers, effective breakage replaces mere abrasion, and the peripheral speed of the rotor can be somewhat reduced. The design of the crushing chamber ensures that all particles are subject to multiple impacts before they can escape as product. The limitation upon this equipment is the resistance of tungsten carbide to shattering: While this material has very high resistance to abrasion, heavy impact can cause it to break, so the feed size must be restricted to 10mm or so, depending upon the friability of the source rock.

The second important stage in the design was to devise equipment capable of selecting the desired product, while removing unwanted filler, and returning oversize particles and some overabundant sizes for further reduction. The Air Screen was designed using a draught of air as a classification medium, allowing larger particles to fall first and to be recirculated, and successively finer material to drop further along the screen chamber. An additional control, or damper, allows a proportion of the coarser particles to be diverted to recirculation, in order to control the top size and grading of the product within close tolerances. This feature allows the US7 crusher to produce the necessary amount of 150µm-1mm grains for an ideal particle size distribution. Fine filler is drawn off at the far end and is collected in a bag filter.

In its original form, this equipment, together with its transport systems, was sufficient to produce sand to the Japanese specification, but the latter forbids the inclusion of more than 7% minus 75μm in the sand, despite the fact that many end users have found advantage in rather higher filler content. Recently most plants supplied have included a “skimmer” after the air screen, to recover the coarser particles up to about 300μm that are otherwise lost to the bag filter. This addition has meant that sand size particles and larger sub-63μm can be returned to the product, improving the sand characteristics as well as increasing recovery.

GENERAL DESCRIPTION AND OPERATION OF THE PLANT

The plant is constructed in the form of two adjacent towers, one carrying the crusher and air screen, fed by a bucket elevator, the other supporting the bag filter and skimmer assembly. The reason for this arrangement is to minimise the footprint, which is very compact, and to enable effective dust encapsulation to be achieved. Provided the plant is properly maintained, dust emission is as near zero as to be insignificant.



Once set to produce the desired gradation, the circuit is electronically controlled by reference to the crusher power consumption, and signals, to the damper and air screen blower, control the recirculation and filler extraction respectively, allowing a constant fineness modulus to be maintained.

The feed material of crusher dust, or other sub-10mm product, must be dry – around 2% water content can usually be expected direct from a crushing process. In some instances the added value may well justify drying, or even further crushing, being applied to low value waste products such as scalpings. Clearly the more filler in the feed material, the more will need to be disposed of after the process, but a rule of thumb is that the process will recover around 80% sand and 20% dry filler. It is usual to condition the finished sand with a small percentage of water, in a small drum mixer, to prevent segregation and maintain consistency.

The process has been applied successfully to a range of rock types, including andesite, basalt, diabase, granite, limestone, and sandstone, and some have been used in recycling and slag applications. The most common application is to produce sand for ready-mixed concrete, but other products are possible, including building sands, playground sand, and so on.

The concrete sands have been found suitable as up to 100% replacement for natural sand, with cement savings possible in many cases. An added bonus is the extreme reliability of the process in making a consistent product, allowing mix design to be controlled within narrow limits. Many operators of V7 plants have made radical modifications to their aggregate processing in order to accommodate increased demand for fine aggregate, and concrete producers find it attractive to have all their aggregate supplies from a single source.

CONCLUSION

The producers of the V7 Sand Manufacturing System seem to have solved most of the problems of making a really high quality sand product from crushed rock. In addition they have gone a long way towards offering a profitable solution to the large accumulations of waste materials such as scalpings and quarry dust that are an inevitable by-product of the concentration on coarse aggregate production. With natural sand supplies becoming ever scarcer and more expensive, the potential for adding value to low-value crushed rock is such that a plant can usually justify its costs relatively easily, even in abrasive situations.

* In this article, the term filler refers to particles smaller than 63μm.

** The term equidimensional describes particles that are broadly of similar dimensions in three axes, as opposed to the more commonly, but less helpfully, used cubical, which does not accurately describe an ideal particle shape.

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