Crushers affect prod

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Throughout the world, there is a prejudice against using manufactured sands due to a lack of understanding of the qualities or characteristics of these materials. One of the main culprits in having manufactured sands accepted as a suitable concrete material is the aggregate industry itself. The aggregate industry typically has branded any crushed product that is less than 4 mesh (4.75 mm) as a "manufactured sand".

This of course is not the case. Manufactured sand should be a product that you have intentionally produced, not merely the waste fraction of a process that is targeting larger aggregate sizes.

In this article, we will investigate the impact that various crushing and process technologies have on the final product quality. As in the previous articles, the characteristics that are of most concern to us for manufactured sand are particle gradation (size), particle shape, and particle surface texture.

The particle size distribution or grading, is controlled by screening or some method of classification. The aggregate particles that are discharged from the crushing circuit are classified by the particles' size. This sizing process obviously does not alter the particle shape, nor will it alter the particle surface texture, as the surface texture of the particle is a property of the parent rock itself.

Of main concern to quality aggregates and manufactured sands, is the shape of the particles. The shape of the particles is influenced by the crushing process, therefore we need to understand the characteristics of the aggregates and sands so that the correct crushing technologies are employed to get the desired quality end result.

Sieve analysis alone is not a good indication of an aggregates quality. If the sieve analysis gave an adequate indication of how a material will perform or behave in concrete or asphalt, we would not have so many problems with the final products (concrete, asphalt etc.) as the materials with the same gradation would behave similarly. As we are all aware, this is not the case. So, when looking at a circuit for producing quality materials, full care and attention needs to be given to the number, and the type of crushers being employed. This is especially true for the tertiary or quartenary stage in the circuit, as this is typically where the final aggregate or sand is produced.

Particle shape becomes more important as a particle gets smaller. This is due to a particles' specific surface. For any given shape, as you half the nominal size, you double the specific surface. See Graphic 1. (Specific surface is the surface area to volume ratio). In concrete and asphalt, aggregate occupies by far the greatest volume. But the binder for each of these products, cement and bitumen, are by far the most expensive item. The amount of binder, or in simple terms glue, that is required to "stick" the aggregates back together in the matrix is influenced by the total amount of surface area that is on the aggregate particles.

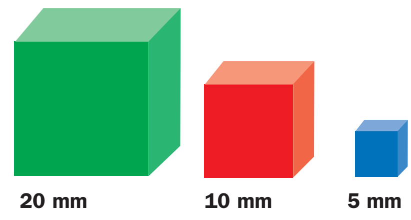
Basically, the less specific surface that the aggregate blend has, the less binder will be required to cement the particles back together. The 20 mm cube has a total surface area of 20 mm x 20 mm x 6 = 2400 mm^2

The volume of this cube is 20 mm x 20 mm x 20 mm = 8000 mm^3

As a simple ratio, the surface area to volume ratio is 0.3. (2400/8000)

The 10 mm cube has a total surface area of 10 mm x 10 mm x 6 = 600 mm^2

The volume of this cube is 10 mm x 10 mm x 10 mm = 1000 mm^3



As a simple ratio, the surface area to volume ratio is 0.6. (600/1000)

The 5mm cube has a total surface area of 5 mm x 5 mm x 6 = 150 mm^2

The volume of this cube is 5 mm x 5 mm x 5 mm = 125 mm^3

As a simple ratio, the surface area to volume ratio is 1.2. (150/125)

This relationship between particle size and specific surface is the main reason that we should be attempting to put larger aggregate sizes into the concrete. Within reason, the top size aggregate should be a large as possible, but should not be more than one third of the concrete lift height, or more than one half of the nominal spacing between the reinforcement. As illustrated above, the larger the particle size, the lower the specific suraface.

The other important point is to realise that as a particle gets smaller in size, the specific surface does get proportionally greater. Therefore, the smaller the aggregate particle, the more important that is has a good shape.

Crushing Scenarios

As it is so important that particle shape is equidimensional, and because the gradation of a product can be altered by some form of classification, we need to look at the impact that crushing technologies have on particle shapes.

It is generally accepted by crushing

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equipment manufacturers, plant designers and operators that the following "rules" apply with respect to the production of cubical or non-flaky or non-elongated particles.

The crushing action of a fully autogenous vertical shaft impactor such as a Barmac Duopactor is generally accepted as the crushing technology that can produce the best aggregate particle shape. The particle shape is achieved through the various reduction mechanisms that are characteristic of an autogenous vertical impact crusher.

Equidimensional particle shape from a Barmac is a result of the impact, abrasion and attrition actions that occur in the rotor and crushing chamber of the crusher. Feed material enters the Barmac and is channelled into a rotor. This rotor hurls the material at very high velocities into a rock lined crushing chamber, where the material rubs, impacts and grinds with itself, eroding the particles so they become equidimensional. It is possible that each particle may spend up to 20 seconds in the crushing chamber, continually having work performed on it, hence the resulting superior particle shape.

The crushing actions of the Barmac Duopactor simulate the actions of nature. The resulting particle shape, especially of the fine aggregate, is of the highest quality. As the autogenous VSI uses rock to crush rock, there are no wear parts directly employed in the crushing process. Therefore, one of the main features of the crusher is that it produces a consistent gradation of product, no matter how much wear is present. This is not the case with other crushing technologies. Along with particle shape, the resulting consistency of sand production is a real bonus to the concrete producer and helps add value to the product.

To establish the advantage that the autogenous VSI gives in manufacturing sand over other crushing technologies we will compare the shape of the particles and conclude the performance of the materials in a concrete application.

Two Crushing Scenarios

We will look at two actual Barmac installations, the first is a manufactured sand installation where the material fed to the Barmac is "waste" cone crusher product. As per the circuit diagram, the minus 10 mm product is screened at 3.0 mm, with the remaining 3.0 mm to 10.0 mm material fed to the Barmac for processing. The minus 10 mm cone product on its own is considered unsaleable or of little or no value. The product from the Barmac is then screened at 5.0 mm and the oversize recirculated.

The second installation has the Barmac as a tertiary crusher, taking a flaky and elongated feed of 40 mm - 20 mm. The desired products from this installation are a well shaped, graded 20 - 10 mm aggregate, a well shaped 10 mm - 5 mm aggregate and a high quality manufactured sand for the concrete industry.

Shape Comparison of Sands

To assess the suitability of the sands for concrete production, we will measure the particle shape by way of the flow cone, as well as

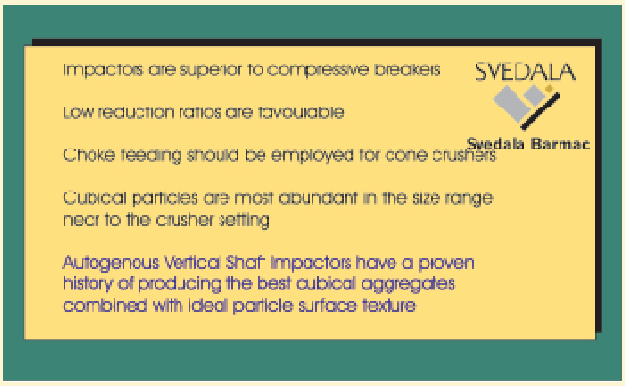


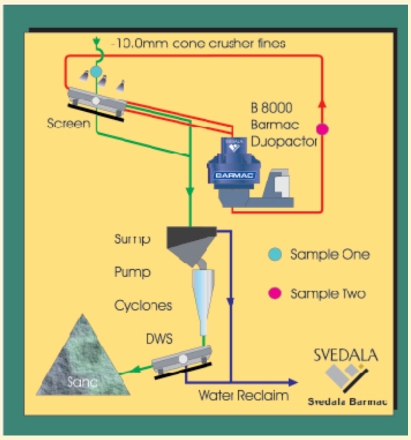
Table 1
Source: Kojovic, T. "Crushing Aggregate Shape and Control," Quarry Australia Magazine, Volume 3, No. 6, June 1995.

PARTICLE SIZE RANGE	COMPACTED VOIDS CONTENT % (PRODUCT - BARMAC)	COMPACTED VOIDS CONTENT % (FEED)
37.5 mm - 25.0 mm	39.6	41.3
25.0 mm - 12.5 mm	37.7	41.0
12.5 mm - 9.50 mm	37.9	
9.50 mm - 4.75 mm	38.1	
4.75 mm - 2.36 mm	38.6	
2.36 mm - 1.18 mm	38.3	
1.18 mm - 0.600 mm	38.4	
0.600mm - 0.300 mm	39.3	
0.300mm - 0.150 mm	40.3	
0.150mm - 0.075 mm	41.9	

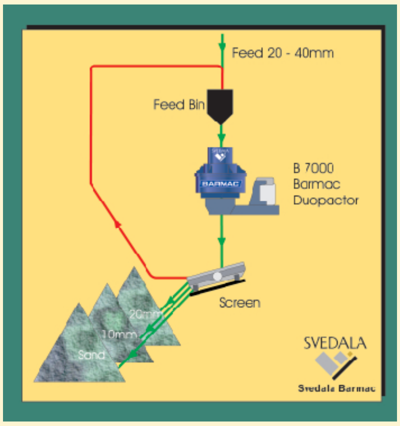
Table 2:
Compacted Voids Content for individual size fractions of concrete aggregates and sand from a Barmac Duopactor. Note the remarkable consistency in results, as well as the shape improvement over the feed material. Also, the Barmac Duopactor does not have a crusher setting, hence the particle shape does not noticeably deteriorate at the ends of the particle size distribution.

Material	Flow Seconds	Void % uncompacted	Water/Cement ratio
Granite Cone fines (Sample One)	38.1	46.5	0.59
Granite Barmac Sand (Sample Two)	32.1	44.5	0.52
Barmac Sand (Tertiary Crushing)	26.4	36.1	0.48
Cone Sand (Tertiary Crushing)	36.3	55.4	0.61

Table 3:
Comparison of the performance of the various natural sands in the mortar flow test. Note the superior performance of the materials processed by the Barmac Duopactor.



Graphic 3: Crushing circuit for the reprocessing of quarry fines. The feed to the Barmac Duopactor is minus 10 mm cone crusher product. The cone crusher product is screened at 3.0 mm and the remaining 3.0 mm - 10.0 mm is fed to the Barmac. The Barmac product is screened at 5.0 mm and the oversize re-circulated.



Graphic 4: Tertiary crushing circuit for the production of high quality concrete sands and aggregates.

looking at the performance of various gradations. The difficult task of measuring the shape of such fine materials as are present in manufactured sands is most commonly done in a sand flow cone. The time for a known volume of material to flow through a fixed sized orifice is recorded and logged against the uncompacted voids content of the same material.

In the first material example that we will analyse, the cone crusher product (minus 10.0 mm, (Sample One)) is a fine grained granite.

The visual appearance of the material is that of an extremely flaky and elongated product. The desired final product being manufactured has to conform to a standard close to the ASTM C-33 sand gradation specifications. Because of this, we believe the final product is lacking in fine material (less than 150 micron). However, the advantages of producing fines, or manufacturing sands in a Barmac Duopactor can still be adequately quantified, through observing the improvements in particle shape.

The particle shape and surface texture both affect the flow time of a particular sample. Among other things, these properties will influence the internal friction characteristics, and hence impact on the flow time of a material. As mentioned previously, the flow and voids tests are affected by particle gradations. But as you can see, the gradation of the two different products is very similar, with the Barmac sand (Sample Two) on this occasion being slightly coarser than that of the cone (Sample One).

However, the materials will behave in two distinctively different ways in a concrete mix. Sample One, the cone material, has a flow time of 38.1 seconds, and an uncompacted voids content of 46.5 percent. These results indicate that the material is poorly shaped and the high flow time (a flow time of less than 30 seconds indicates a workable sand) tells us that the sand would make it almost impossible to produce a concrete that would be easily placed. Both of the results indicate poor performance of the sand in a concrete mix. This is obviously the reason why the crusher fines have required re-processing.

The Barmac processed material (Sample Two) is in high demand from the concrete industry. The reason for this is that the particle shape from the Barmac Duopactor has been enhanced to the point that the material is useable - even though the sand specified is deficient in the fine fractions that gives the manufactured sand an edge over natural sands.

The flow time for the Barmac processed sand significantly drops six seconds down to 32.1 seconds, with the uncompacted voids content falling to 44.5 percent. It should be noted at this stage that both of these figures would be improved if the bottom fraction of the grading were to be identical to the cone crusher fines sample. In real terms, the improvement in the sand after it has been processed with the Barmac Duopactor is that the concrete made with this sand is now workable. And the reduction in uncompacted voids content may represent a strength increase in the concrete in the vicinity of 4 MPa, in a 30 MPa concrete mix.

We believe that if the gradations were allowed to be modified to those discussed in earlier articles, ie. an increase in the minus 150 and 75 micron size ranges, the difference between the sands would be further amplified.

Quality tertiary crushing

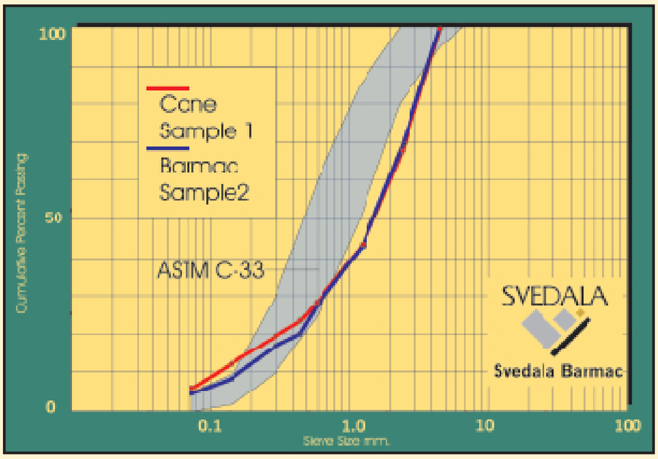
The first example was evidence of how a Barmac Duopactor can be utilised to turn other crushers waste products into premium, sought after materials. However, one of the major benefits of having a Barmac Duopactor as a Tertiary or quartenary crusher is that the low value or unsaleable products are not generated in the first place.

Because the voids content of narrow size fractions of materials tells us so much about the individual particle shape and specific surface, we have analysed this Barmac Duopactor installation where a flaky and elongated 40 - 20 mm is used as the feed material. The voids content of each sieved size fraction has been determined to ascertain where particle shape deteriorates. As stated by Kojovic, particle shape gets less equidimensional the further the particle size gets from the crusher setting.

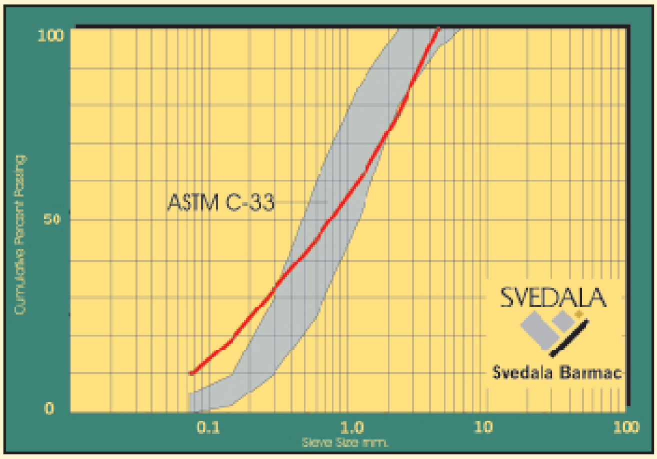
As the Barmac Duopactor has no such setting mechanisms, particle shape remains cubical or equidimensional throughout the entire gradation. Also, as an autogenous VSI has no wear parts that are directly used in the crushing process, gradation does not alter with wear. This is an extremely important feature for a concrete producer - especially in the sand fraction of a concrete mix.

The consistency of the compacted voids content indicates that the particle shape does not appreciably deteriorate throughout the entire particle size distribution. The actual compacted voids content of each size range is particularly low, which tells us that the particle shape is as close to equidimensional as you can get for a granite type product. A compacted voids content below 40 percent in any size fraction of an aggregate gradation will help provide dense, high quality concrete.

The corresponding flow and voids content for the Barmac Sand are: Flow: 26.4 seconds; Uncompacted voids: 36.1 percent. The graded aggregates from this section of the crushing circuit, a 20 mm graded concrete aggregate, a 10 mm - 5 mm graded concrete



Graph 3: The two gradations of minus 4.75 mm products. Note that the Barmac product is slightly coarser at the fine fraction (minus 1.0 mm) which will have a detrimental effect on voids and flow results due to the smaller volume of ultra fine material.



Graph 5: Minus 4.75 mm gradation of the Barmac sand generated from the tertiary crushing circuit.

aggregate and the Barmac Sand are all used in concrete production. There is no waste from this process as every particle manufactured is of premium quality and the fine materials are included in the Barmac Sand. This is illustrated by the compacted voids content results being low down to the 75 micron size range.

The relatively fast flow time indicates a sand that will assist concrete workability. Once again, as you can see, the sand gradation is outside the normal natural sand specifications.

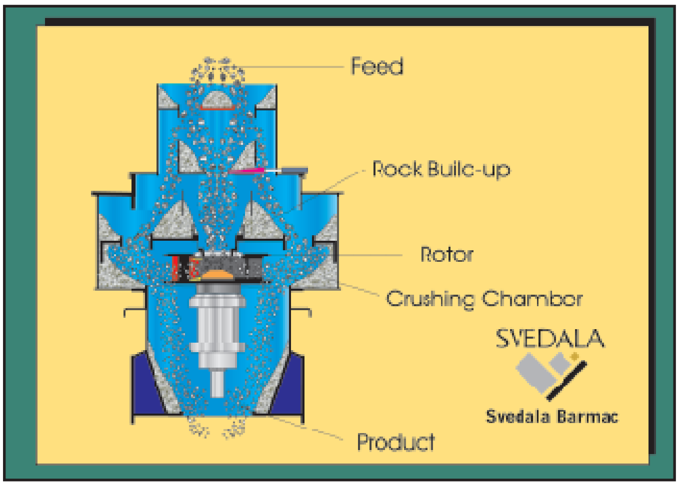
A nearby quarry, utilising cone crushers in their tertiary crushing circuit, have a sand that has a flow time of 36.3 seconds, and the voids content is a very high 55.4 percent. Both of these figures indicate that the material is unsuitable for concrete, but, the gradation is similar to the well-shaped Barmac products. The flaky and elongated material is evident from the photograph below.

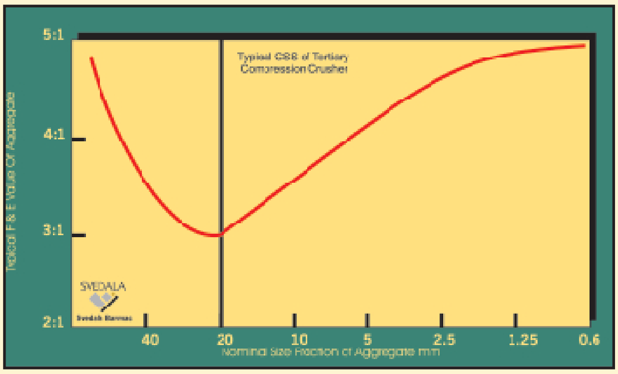
As a guide to how sands will perform in concrete, a quick test is to measure the quantity of water required to obtain a fixed workability. The test is performed on the minus 4.75 mm material and a fixed volume of cement. As stated earlier, the quality of concrete is largely dependant on the amount of water required to obtain the desired workability. The four materials that have been compared above yield the following water cement ratios:

When taking into account the importance of particle shape, especially as particles get into the sand sized fractions, we should study more closely the points raised by Kojovic in Table 1. If we look at point four in this table, we can see that the particle shape deteriorates the further the particle size is from the closed side setting of that crusher. In a typical relationship between a shape test, say the Flakiness and Elongation test, we would see the following type of result.

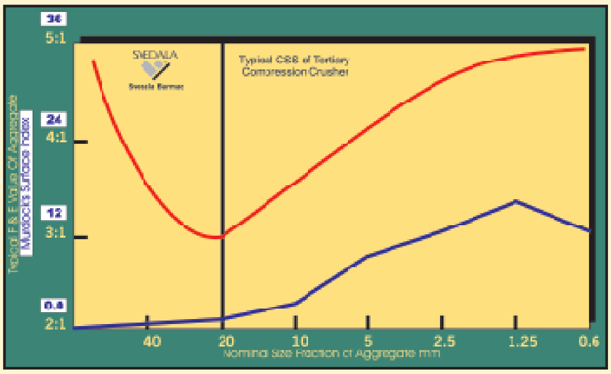
In an earlier article in this series, I mentioned Murdock's Surface Index. If we were to plot this index versus the typical shape result for a compression type crusher in the tertiary stage of the crushing circuit, we can see the following.

Comparing this with the results generated from the Barmac VSI, and you can see the reason why the autogenous VSI produces sands that are far superior to those produced in a compression type crusher. ■

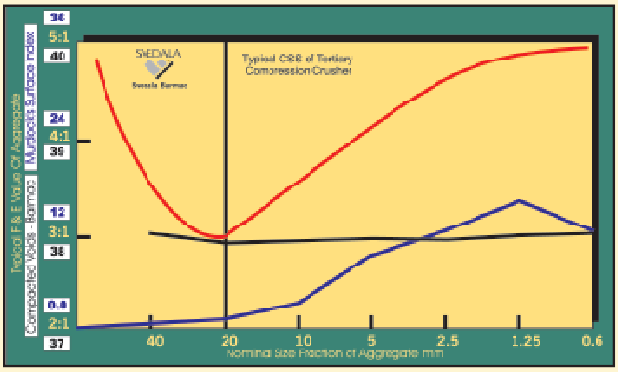




Graph 6: The closer the line gets to the axis on this graph represents the more equidimensional the particle shape.



Graph 7: Note that the particle shape of an aggregate needs to the best at the highest point on Murdock's surface Index. Note that the requirement for good particle shape does not typically correspond with the setting at which a compression crusher produces its best particle shape.



Graph 8: Note that the particle shape of the materials that have passed through the Barmac Duopactor remain relatively constant, especially at the size fraction that Murdock has established as being the most critical for concrete sands.