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AN EXPERIMENTAL SAND PROJECT

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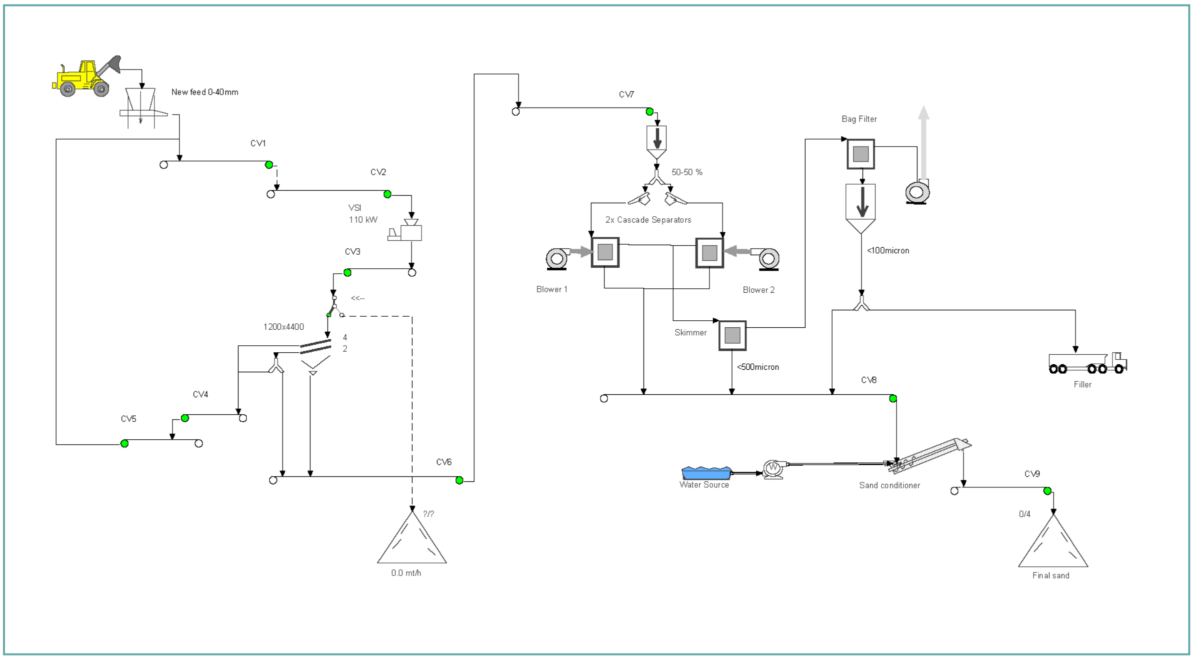
1 BACKGROUND

The plant was commissioned to explore the opportunities for manufacturing high quality sand, principally but not exclusively, for use as fine aggregate in ready-mix concrete. Its function is simply to improve particle shape to an acceptable degree, realign the particle size distribution according to whatever specification is required, and to exercise control over the microfines (defined as material passing a 63µm sieve) content. These are the factors that can be affected by existing mechanical methods. Dry processing was chosen because it opens up possibilities for the creation and sale of subsidiary products, but also on grounds of cost, space requirements, waste handling and disposal and other environmental reasons.



2 PROCESSING PLANT

The plant consists of two sections:

- A Vertical Shaft Impact (VSI) Crusher in closed circuit with a vibrating screen.
- A three-stage air separation array

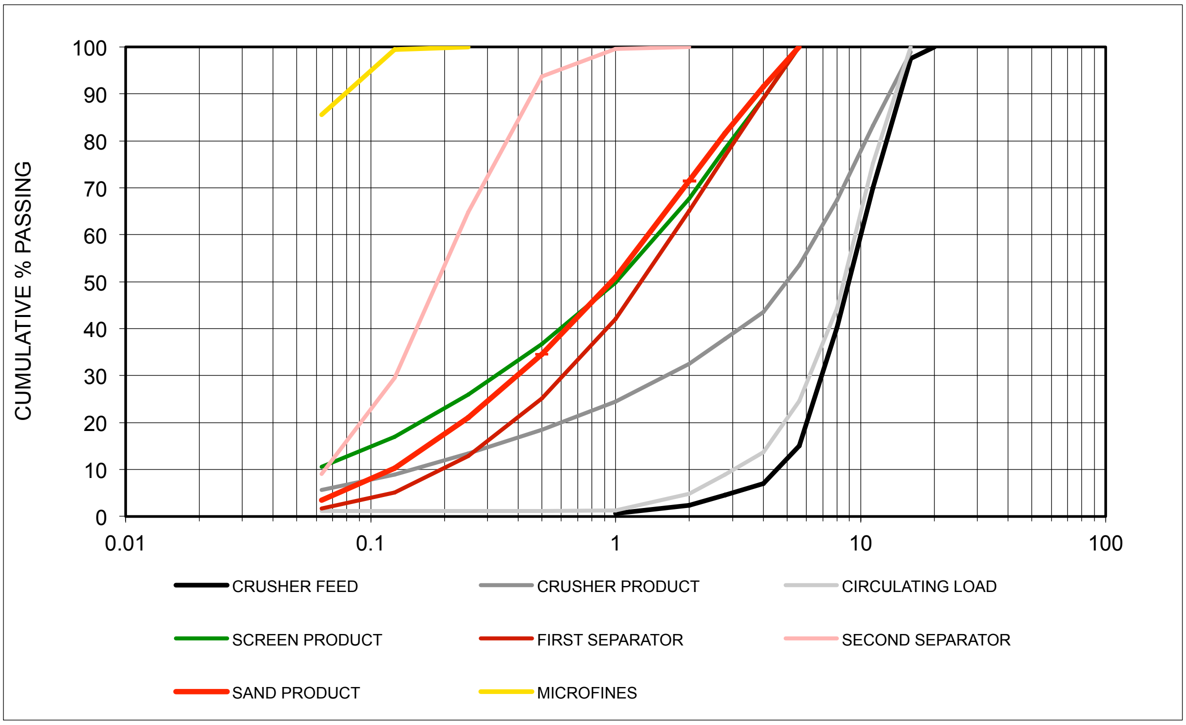
The VSI is sized to accept a range of feed sizes from crusher dust 0-4mm, up to single-size coarse aggregate 20-40mm, with a throughput capacity including circulating load of around 70t/h, depending on rotor speed. Its function is two-fold, namely the size reduction of particles to suit the size range required for the sand product, and to impart particle shape greatly superior to that of the feed material. The latter is achieved by a combination of impact crushing, attrition, and abrasion between the feed particles as they pass through the machine.

The screen is so arranged as to set the top size of the sand product on the top deck (usually around 4mm), and to allow selective recirculation of a proportion of the coarser sand particles (usually around 2-4mm) along with the top deck oversize. This results in the ability to control the shape of the grading curve to achieve good packing density, a primary objective in the production of sand.

The air separation system consists of coarse and fine separators and a bag filter:

The coarse separator makes a rough cut, allowing all of the product retained on around a 500µm sieve to pass through and form the bulk of the sand product. The volume of smaller-sized material included with the underflow depends upon the adjustment of the air-flow, and, crucially, upon the moisture content of the feed material.

The fine separator captures larger particles, carried over from the coarse separator, down to around 125µm, and in most cases adds this material to the coarse underflow, so completing the final sand product. The remaining fine material passes through to a bag filter where it is collected for disposal or further treatment.



Test Feed granite 8/16mm

The sequence is illustrated by the curves taken from each stage in the example above.

(Note that all sieve tests were carried out dry, so true filler contents would be rather greater. The above example gives a figure of around 11% in the feed, typically these have varied between 10 and 20%)

3 PLANT SET-UP

Adjustments available to the operator of the plant are as follows:

- Feed rate: This is the combination of new feed and circulating load, which are automatically blended in the feed hopper. The adjustment is performed by altering the belt speed mechanically or electronically on CV1, or by altering the setting of the discharge gate on the feed hopper. Normally this would be set to a given a load (in this case170A) on the crusher inverter read-out.
- Screen deck apertures, usually around 4mm on the top deck, 2mm below.
- Bottom deck recirculation proportioning by means of removable blank panels at the end of the bottom deck (everything retained on the top deck is re-circulated).
- Separator air draft is controlled by a combination of blower and exhaust fan volume: The blower fans are adjusted by means of movable doors which vary the inlet aperture for each fan, while the exhaust fan has inverter speed control. The amount of material required to be extracted informs the exhaust fan speed, and the blowers are adjusted so as to maintain negative pressure in the cascades.
- The skimmer is adjustable to alter the cut point of the fine separation.

In deciding the set-up of the plant, it is important to keep in mind:

- The best results are not always obtained with the maximum load on the crusher. This aspect has not been formally investigated, but experience with finer feeds has indicated that rotor load may be a factor in optimising the particle shape.
- The best results are not always obtained with higher rotor speed: This should be the subject of comparative testing before a final set-up for production is decided upon.
- Setting the top size of the final sand usually involves the selection of screen panels of different apertures on the top deck to ensure the correct proportion of particles nearest the top size
- Bottom deck screen panels may also be varied according to the grading required
- It is necessary to recirculate some part of the material retained on the bottom deck to obtain a particle size distribution with the optimum packing density.
- Moisture content: This should be as low as possible, and for consistent and repeatable results <1% is desirable. Some rock types are more reluctant than others to release adhering micro-fines, and this seems to apply particularly to the more basic rocks such as basalt. Unless the material is suitably dry, varying the air draught in the separators will have an inconsistent effect.

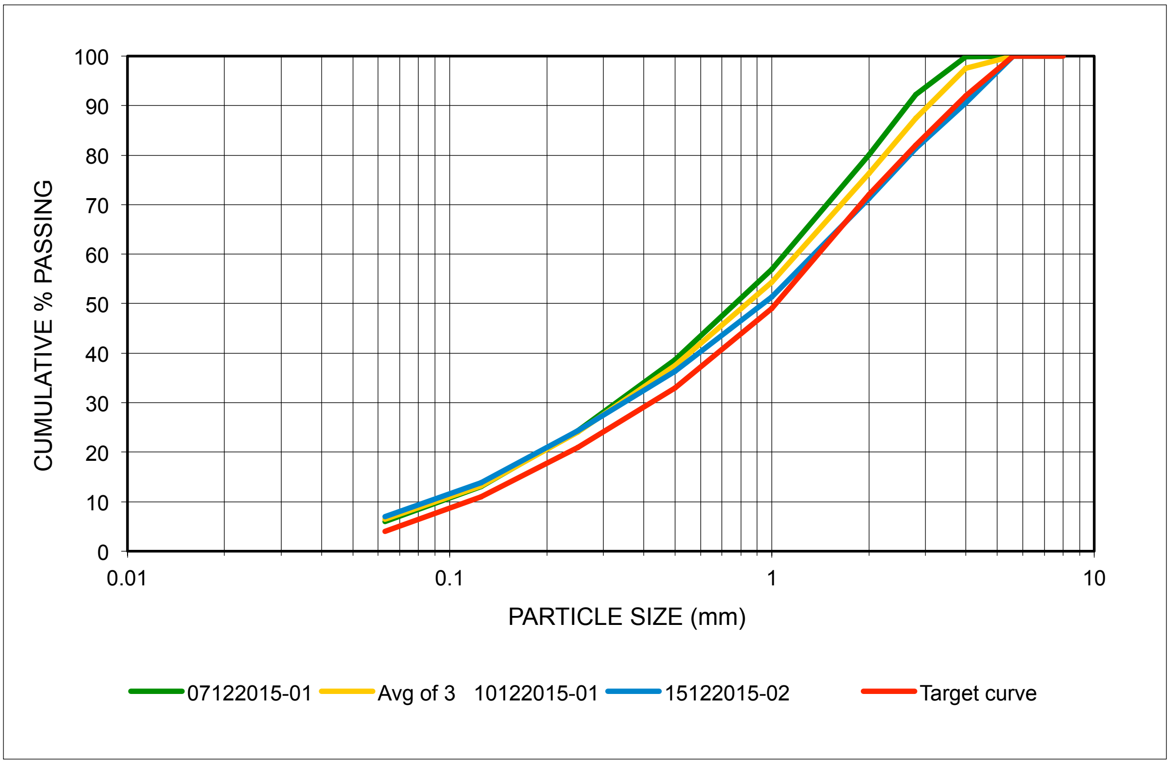
4 TEST PROGRAM

After an initial period of commissioning, testing, and improvements to the set-up of the plant, a number of trials were carried out as described below. The list is representative, and will serve to illustrate the ability of this plant to produce sands close to a given specification. Sand testing consisted of dry sieving, and flow characteristics measured using a flow cone to determine flowability and un-compacted voids content.

4.1 INITIAL TESTING

At this time we were mainly concerned to produce some usable sand product with a granite feed, to allow product testing in concrete to proceed without delay. We started with our own estimate of what was required, and the sand produced from a variety of feeds looked and felt satisfactory in the absence of any firm specification. Our view was that we should concentrate initially on producing good particle shape, with a size distribution more or less as follows: Maximum grain size 4mm / >80%passing 2mm / c.40% passing 500micron / <10% passing 63micron.

We subsequently received a request to try to vary the grading to make it coarser (90% <4mm), as shown in the attached grading curve, which also shows our progress towards that target. This was accomplished by a change in stages of top deck screen aperture.



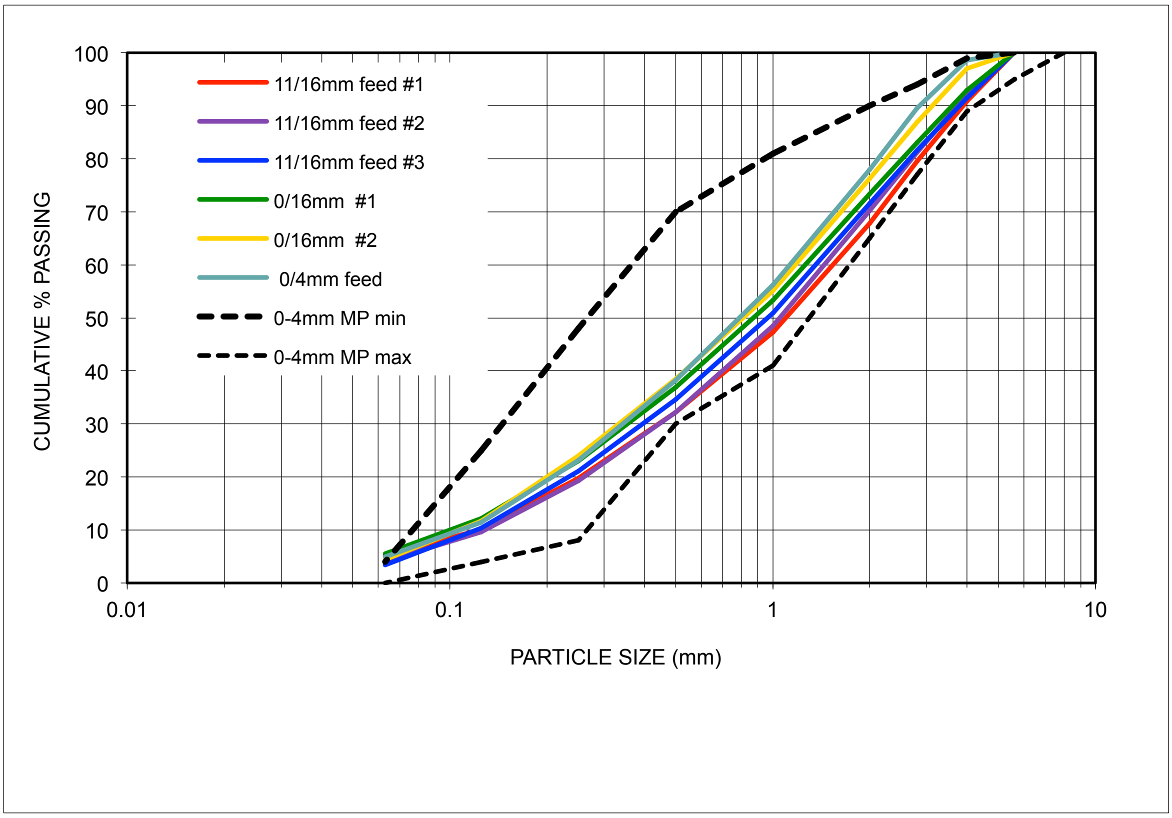
The graph above shows the effect of changing the aperture of the first screen cloth on the top deck from 4mm, through 5mm to 6mm, leaving the remainder of the deck at 4mm.

We found we were able to extract around 50% of the sub-63micron from the screen product, in spite of increasing moisture in our stock of feed material (it was getting wet through capillary action from the damp floor of its storage tent). We made limited adjustments to the separators at that stage, but we found that very little material larger than 125μm was reaching the skimmer, so we concluded that the air velocity in the cascades could be increased, and the skimmer given more work to do. However, it was noted that increased moisture had a marked effect upon separation efficiency, most especially with basalt feed material.

4.2 TESTS WITH GRANITE FEED MATERIAL

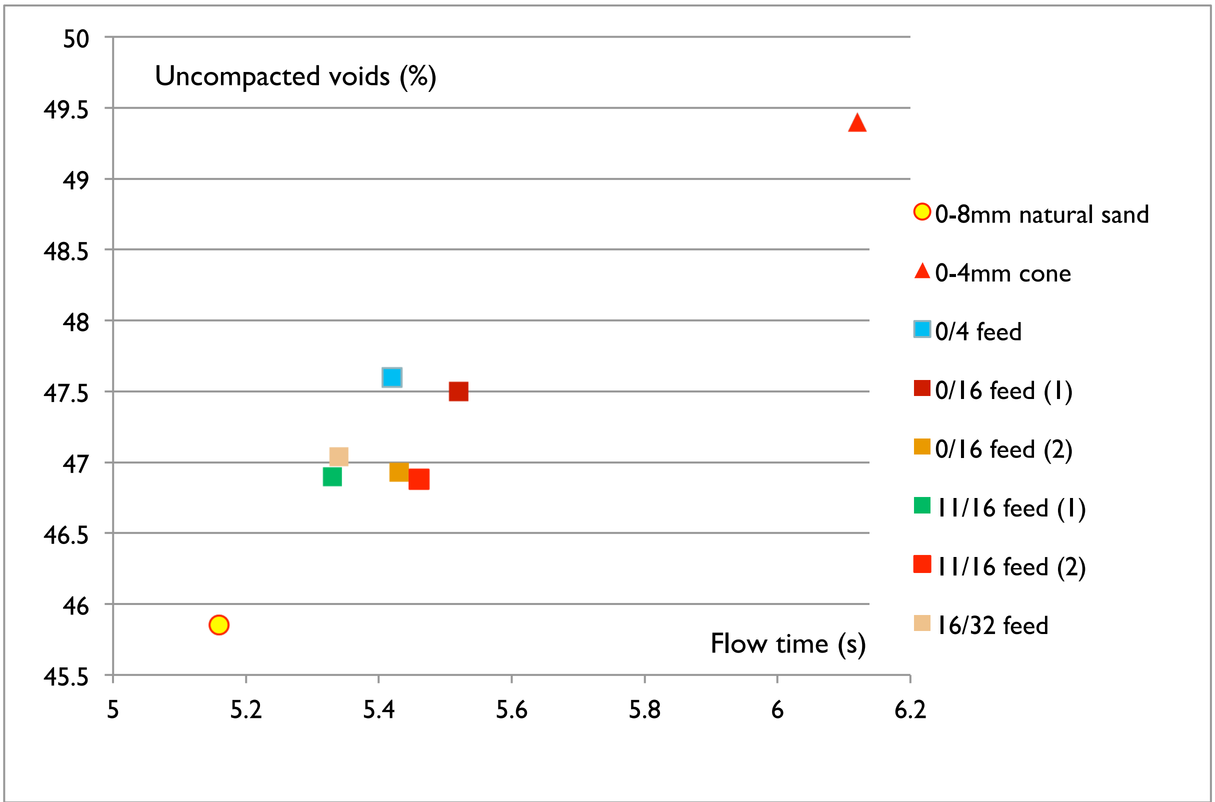
4.2.1 Production of concrete sands

A number of test runs were carried out with different feed materials, illustrated by the grading curves and shape analyses below. While they all fit within the commonly-used European Standard EN12620 0-4mmMP PSD specification, note that the gradings can be adjusted by plant setting changes previously described.



While it is tolerably easy to reduce the filler content to six or seven percent with feeds up to about 2% moisture, we have found that it needs to be less than 1% to achieve very low levels of filler. Granite material taken directly from a contract cone crusher on site was satisfactory providing that dust suppression with water sprays - never an effective method - was not used.

The chart below shows that sands produced by the plant have been of similar particle shape, with flow times and un-compacted voids ratios in the same area. This chart displays the results from a made-up grading constructed from the individual fractions in the same proportions to allow like-for-like comparison. Also shown are values for the local natural sand and cone crusher products to the same standard grading. It is interesting to note that sands made from different feeds, and thus with different circulating loads in the crusher circuit, are so similar. It was equally unexpected that open and closed circuit operation with granite material made little difference to these qualities, although this may not hold true with other kinds of feed.



4.2.2 Viability of coarse and fine aggregate production together

Purpose of tests

As an extension to experimental work it was decided to test the effect of extracting a proportion of the circulating load as coarse aggregate, in addition to the normal sand output, in order to provide increased revenue potential from the plant.
This appeared to have no operational drawbacks according to the Aggflow model, and tests were carried out onto ascertain the nature and extent of any effect upon the sand product that might occur as a result of reducing the size and volume of the circulating load.

Test Procedure

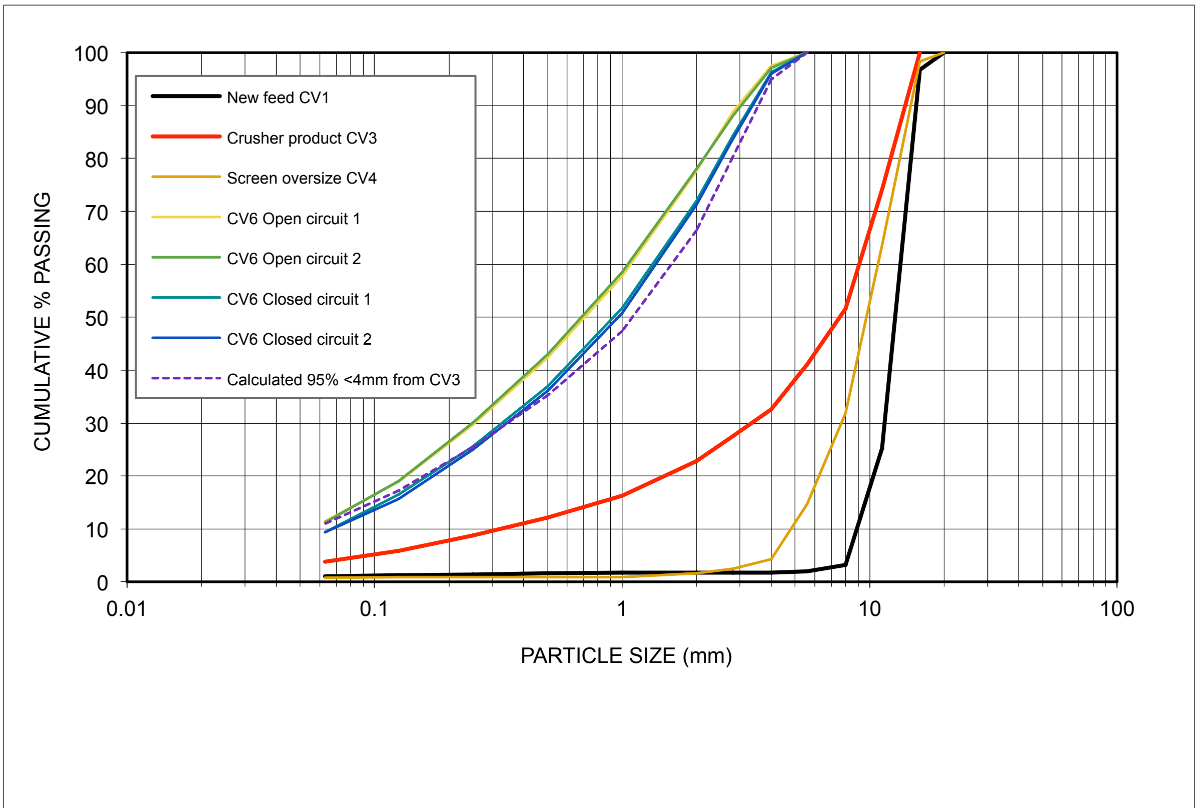
A simple test was devised, involving only the crusher circuit: 11/16mm feed material was used because it was dry and available. This was fed to the crusher in the normal way, with and without the usual circulating load returning to the crusher. No other adjustments were made, except in order to maintain a similar feed rate to the crusher, for which it was necessary to increase the speed of the feed conveyor for the open circuit test. The normal PSD and particle shape tests were then performed on the sand product, and gradings were also taken from the feed, crusher product, and screen oversize streams. The air classification system was switched off, no attempt was made to reduce the filler content of the sand, and the screen set-up was not altered to adjust the sand grading curve, since these are readily adjusted in production, but the all-important particle shape is unaffected by anything except the crusher and its feed, and direct comparison is therefore possible.

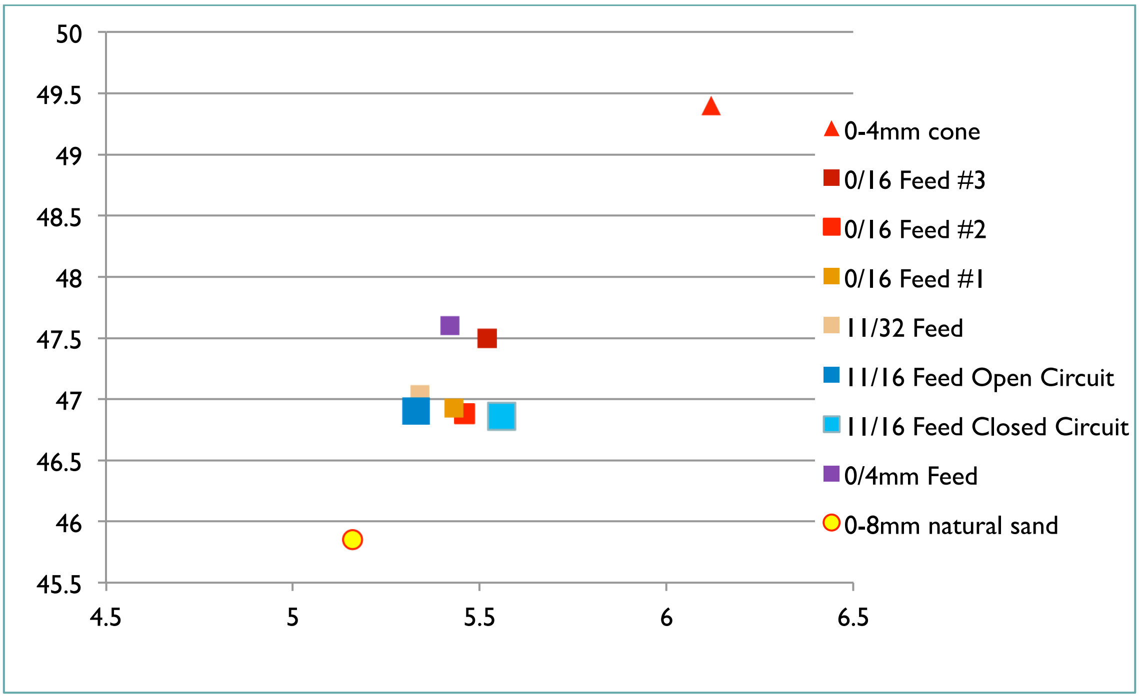
Results

Sieve tests were carried out on the flow streams, i.e. feed, crusher product, circulating load and final product. Note that no filler extraction was attempted. Please refer to the grading curves attached.

It can be seen that the sand product from the open circuit is somewhat finer than that from the closed circuit. This is probably due to the poorly-shaped feed material being much easier to reduce in size than well-shaped circulating material. The grading curve can, however, be quite easily adjusted by manipulating the screen set-up, as we have seen from previous tests.

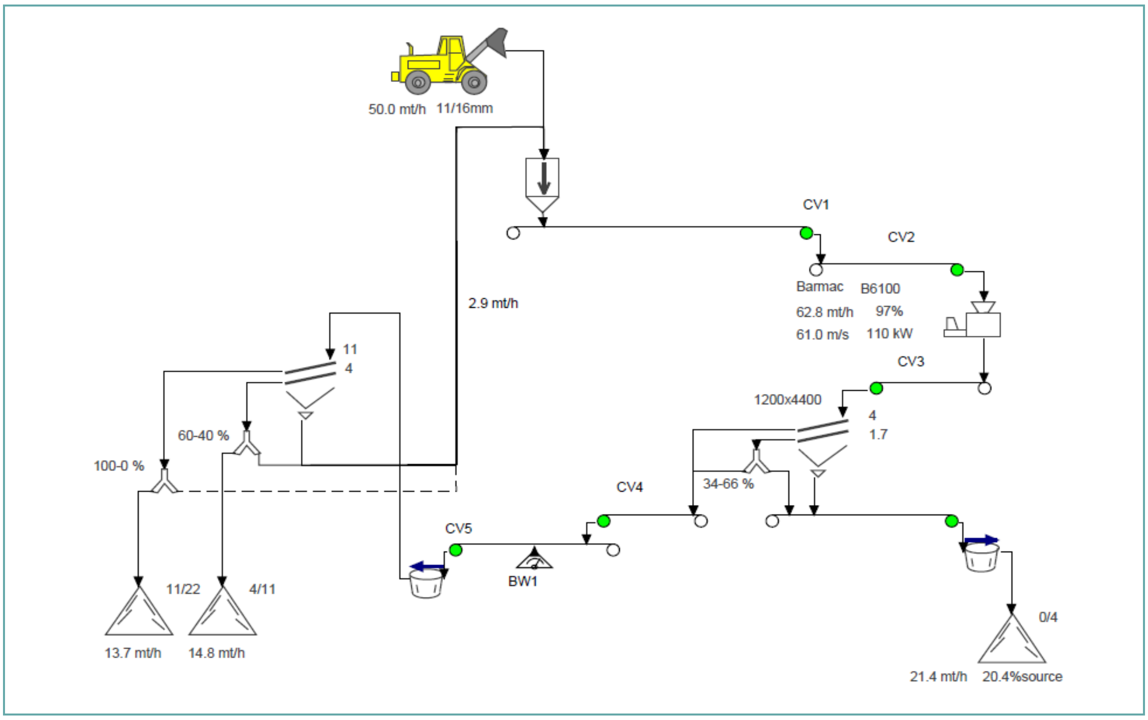
Shape testing was performed on the single-size fractions and the Standard Grading, with the results of the latter attached. Surprisingly, the results display very little real difference in particle shape.





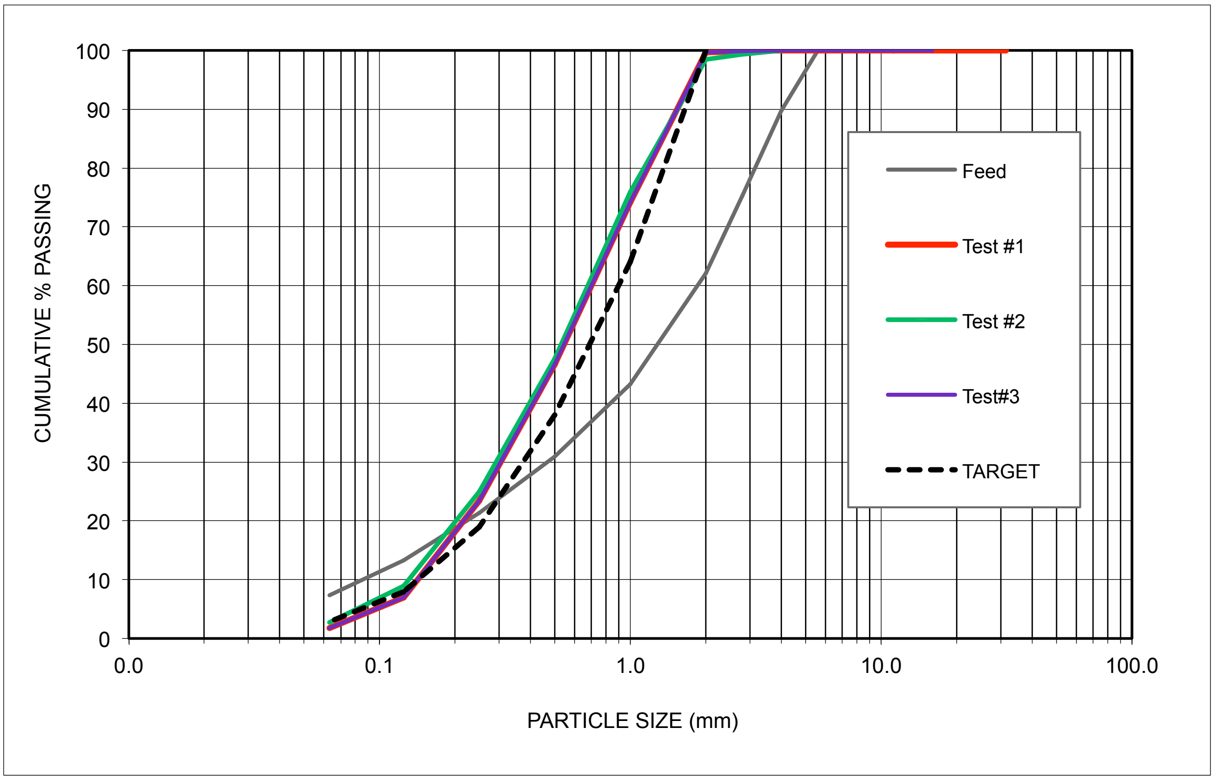
Conclusions

There seems to be no reason why, with granite material at least, removing a proportion of the circulating load as coarse aggregate should make any real difference either to the quality or quantity of sand produced. Depending on market requirements, a single product could be taken with a two-deck screen inserted in the closed circuit, two fractions would require three decks. The oversize could be taken as an additional product, although it might be rather smaller than customers currently expect, and might be better recirculated. The diagram below gives a possible scenario, but it should be borne in mind that some adjustment to screen set-up and the extraction of filler would be required to achieve a suitable sand product. The new screen is shown to the left.



4.2.3 Manufacture of special sand

We were asked to produce a 0/2mm sand containing very little material below 125µm for a specialised application. This was achieved by re-circulating all of the material retained on both decks of the screen, and turning off the rotary discharge from the fine separator so that all the overflow from the coarse separators was carried through to the bag filter. Feed of 0/4mm cone crusher dust was used as it was available and dry, and is also a very economical feedstock both because of its low value and lower crushing requirement than larger fractions. Around 40t/h of this product is achievable from this plant.

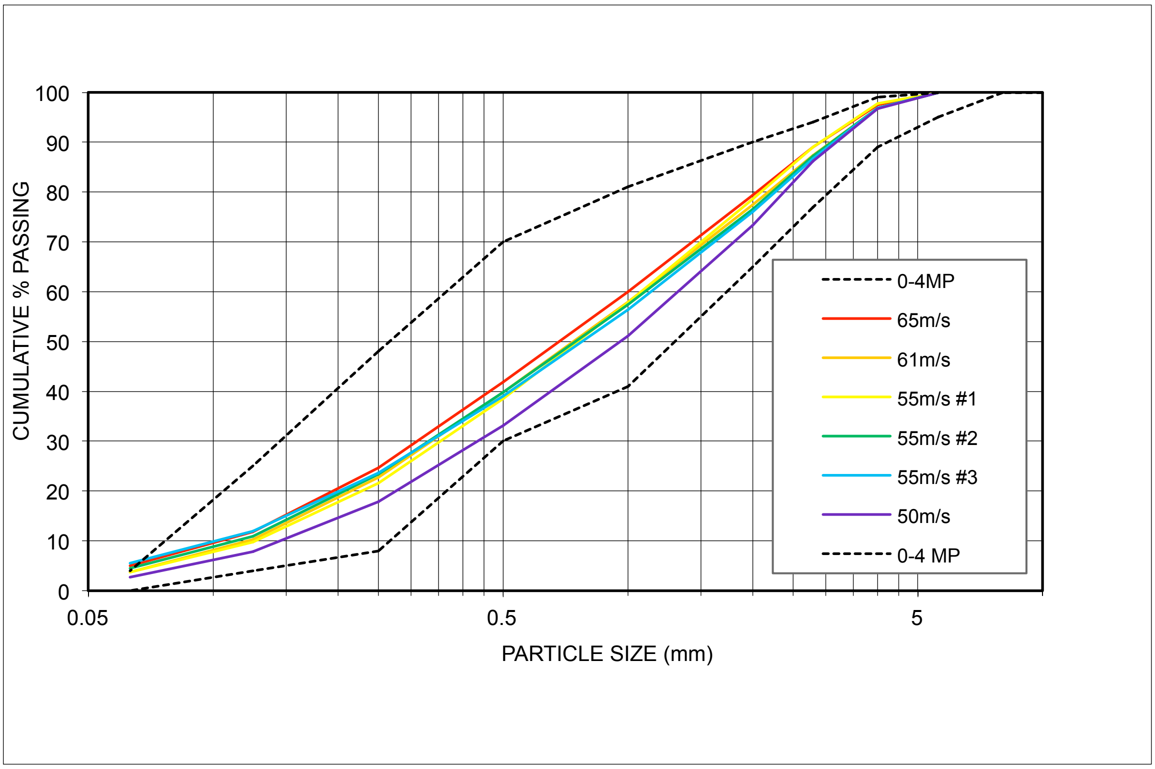


While the resulting sand was not a perfect match with the required target, this test amply demonstrates the flexibility of the plant, and a simple change of screen media would provide a grading very close to the specification. Particle shape was tested on the Standard Grading mentioned previously, which necessitated adding around 5% by weight of 2/4mm grains of material from previous tests, as this sand contains none. The resulting flow time and voids ratio were comparable with those obtained earlier with coarser sands.

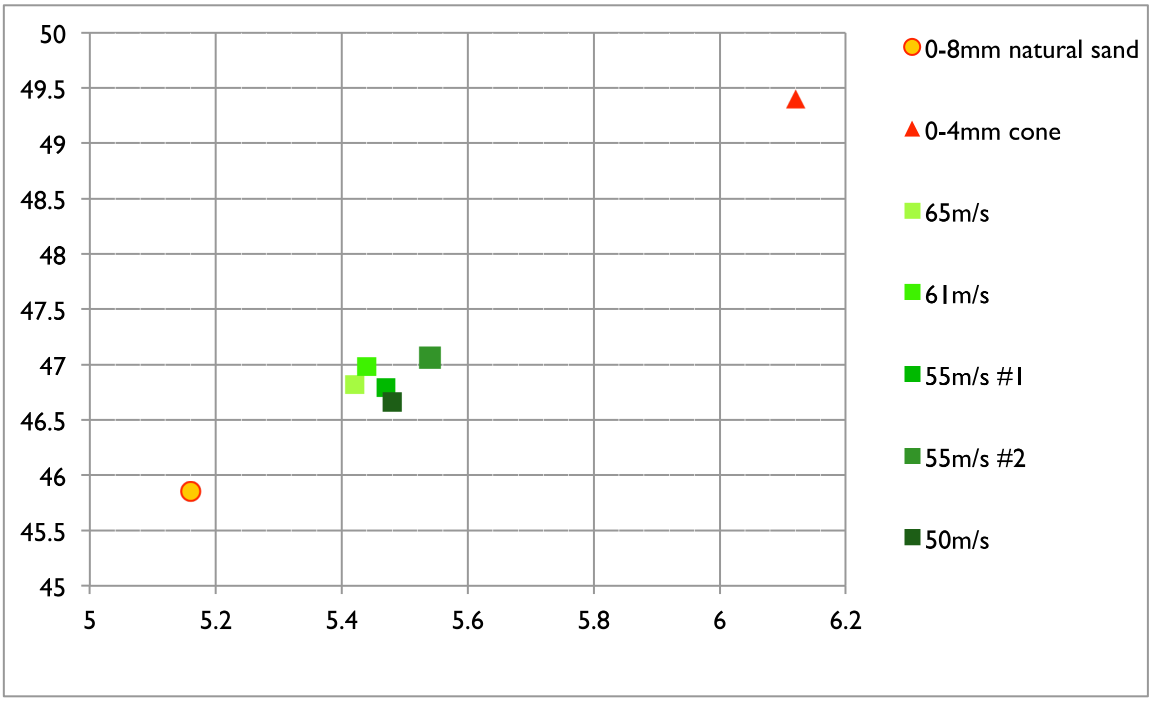
4.2.4 Rotor speed tests with granite feed material

A number of tests varying the rotor speed were performed using a 0/16mm granite feed. This material proved quite easy to process, producing a good particle size distribution with easily controlled micro-fines. This was in part the result of the low moisture content, due to the improving climatic conditions as we moved into Spring.

In these tests the resulting gradings followed more or less the expected pattern, with the finest psd corresponding to the fastest rotor speed. What was slightly surprising was the small difference between 55 and 65m/s, with a more prominent lowering of the curve at 50m/s.



At the same time, there appears to be very little difference in the shape results whether the rotor speed is 50 or 65m/s, and longer term testing is needed to find the optimum.



5 CONCLUSION

This report is limited to the results of testing of granite feed of different particle size distribution. Experience with other rock types indicates that results are fairly consistent as long as moisture and clay content is kept low, making this system ideally suited to inclusion in a dry aggregates process:

- We have shown that the general layout of the process works fairly well in providing a satisfactory control over all aspects of particle size distribution, but only if the feed material is adequately dry.
- More research into the ideal rotor speed, and, indeed into rotor design, should be carried out: We have established that the commonly held belief that particle shape improves with rotor speed is not necessarily so, and it may be more a function of the geology than we supposed.
- When enough filler is extracted from dry feed, we may contemplate measured return of micro-fines to the sand product, but the existing arrangements on the plant for doing so would not be sufficiently accurate and need to be reconsidered.
- No results have been received to date from the PSD tests (arranged elsewhere) on the micro fines gathered from various points in the process. These are essential for us to understand fully the effects and benefits or otherwise of the extraction/reintroduction process.
- Further tests into the effect of adjusting the second separator (skimmer) are needed. This would best be done during a longer-term test or even during production. The tests in all cases so far have been statistically rather too small to be completely reliable, and when the plant is engaged in longer production runs, the sampling intensity should be maintained and results regularly reappraised.
- A test in which the sand was processed through the classifier system twice demonstrated that a second cascade separator installed in series would be very effective in dealing with difficult material.
- The flow time results should be weighted according to Specific Gravity to aid comparability. For this purpose it is essential to obtain accurate SG figures for all feed sources. A quick calculation applied to the average flow time for basalt feed shows the revised figure would be close to that of granite, these being the fastest and slowest times we have yet obtained.
- The proof of the value of the process lies in the application of the material in ready-mix and other concrete. Meaningful results from concrete tests are awaited, preferably not merely the substitution of manufactured sand for existing natural sources.