

Sand solutions: Replacing natural sand in concrete

With natural sand deposits the world over drying up, there is an acute need for a product that matches the properties of natural sand in concrete. **Sven-Henrik Norman** discusses the merits of manufactured sand from crushed rock.

In the last 15 years, it has become clear that the availability of good quality natural sand is decreasing. With a few local exceptions, it seems to be a global trend. Existing natural sand deposits are being emptied at the same rate as urbanisation and new deposits are located either underground, too close to already built-up areas or too far away from the areas where it is needed, that is, the towns and cities where the manufacturers of concrete are located.

Environmental concerns are also being raised against uncontrolled extraction of natural sand. The arguments are mostly in regards to protecting riverbeds against erosion and the importance of having natural sand as a filter for ground water.

The above concerns, combined with issues of preserving areas of beauty, recreational value and biodiversity, are an integral part of the process of most local government agencies granting permission to aggregate producers across the world.

This is the situation for the construction industry today and most will agree that it will not change dramatically in the foreseeable future. Crushed aggregate is replacing natural sand and gravel in most countries. Statistics from Norway (Table 1) show a common trend in many parts of the world.

IS MANUFACTURED SAND THE NATURAL REPLACEMENT?

For particle sizes upwards of 4mm, crushed aggregate can replace natural sand in most construction applications unless there are specific requirements for a very rounded shape and smooth surface. This is probably why there has been a natural shift towards crushed aggregates in most markets over the past three decades, as illustrated in Table 1.

For fine aggregates (by European industry standards, products under 4mm), the replacement of natural sand in concrete is a more complex issue.

Historically, fine aggregate has been a by-product of the crushing and

TABLE 1

Year	PRODUCTION VALUE IN MILLIONS (NORWAY)					MILLION M ³ (2002)
	1982	1991	1997	2000	2002	
Sand/gravel	1000	900	900	760	590	15
Crushed aggregate	800	1350	1859	1825	1950	35
Total	1800	1920	2759	2585	2540	50
Sand/gravel %	56	47	33	29	23	

Source: Svein Willy Danielsen, Sintef



screening process. Due to its rough surface texture, flaky and elongated particle shape and often inadequate size gradation, its performance in concrete has been poor. Water demand has been very high in order to achieve a workable concrete. This has understandably caused many concrete manufacturers to shy away from crushed sand.

In recent years, a change has occurred, driven by the sometimes acute need for a product that can match the properties of natural sand in concrete. A lot of research and development projects have been initiated on a national basis, both by manufacturers' associations and by individual companies.

In general, the findings point towards good possibilities of replacing natural sand with crushed fine aggregates, with other positive effects on concrete. The example in Figure 1 shows higher 28-day compressive strength achieved with manufactured sand from Velde Pukk A/S in Norway, compared to a high quality reference natural sand.

An often noted conclusion in various research and debate forums is for a change of view and mindset. In order to succeed, aggregate producers must move away from using the "waste" of an aggregate plant as a direct replacement to natural sand in concrete and instead look at the complete process needed to produce a sand with the right properties. The term "manufactured sand" has emerged as a fitting description to material that has been produced to meet the quality requirements from the concrete industry.

However, for an aggregate producer, it is not easy to define the quality requirements for

manufactured sand. While there is a well-defined set of standards describing the properties of coarse aggregate (shape index, elongation index, PSV value, etc), the requirements for fine aggregate are not so easy to define. Particle shape - crucial for fresh concrete workability - is not easy to measure and describe for particles at 0.063 to 0.5mm, for example.

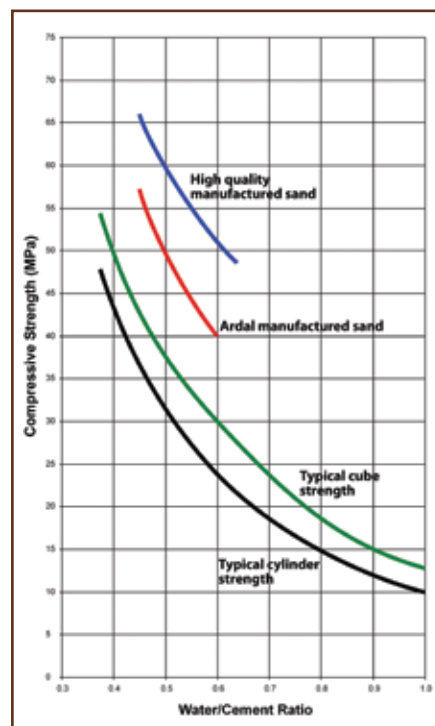
THE LEVEL OF FINES

The fines content of manufactured sand is also important. This is often higher in manufactured sand than in natural sand because the fines produced in nature's "sand production process" have been washed away. Industry standards, like ASTM C33 and concrete producers' specifications for fine aggregate, allow limited amounts of fines (minus 0.063 - 0.125mm particles) in the fine aggregate. Even if recent research and more commercial examples point towards the advantages of using higher amounts of fines, the optimum amount of fines will vary according to the type of concrete for which the sand will be used. Hence, there is a need to separate the fines and then blend them back in, regardless of the required level. Research from Chile (CDT - Corporación de Desarrollo Tecnológico) has sought to establish the optimum level of fines for different concrete qualities (see Figure 2 on page 26).

SAND SOLUTIONS

Metso Minerals has identified the need to develop systems and processes that will help customers find a market for high quality manufactured sand. To this end, a work group has been assembled to bring together the company's wide experience in sand

FIGURE 1



Source SINTEF

production. The company's solutions have been optimised from customer feedback and field success.

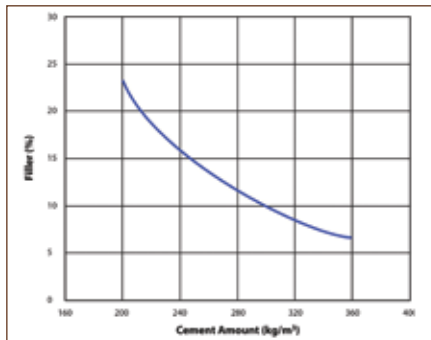
Metso Minerals' Sand Solution equipment has been rationalised based on what works. Efficient crushing and screening systems are utilised to reduce production costs and to offer consistent product quality. This allows customers to drive down total production costs while maintaining high product yields.

CIRCUIT SELECTION

To ensure the highest quality of sand is



FIGURE 2



Source CDT



Operating principle of the AC27/AC30 gravitational inertial classifier.

produced, all feed material must pass the crusher at least once. The selection of the crusher is detailed in Table 2.

Manufactured sand typically contains an excess of material from zero to 0.25mm compared to the concrete grading specification envelope widely used in the industry. This is outside the practical operation range for most conventional vibrating screens, so the traditional way to remove these fines is through wet process equipment like sand wheels or hydrocyclones.

The Nordberg AC Series air classifier range uses air instead of water to remove the excess fines from manufactured sand. The advantages are two-fold:

1. No need for water and then water treatment or recovery, which can be costly.
2. Dry end products mean potential savings in production cost as there is less need for drying.

CRUSHER SELECTION

Crusher selection is based on the abrasiveness of the source rock, feed fraction to the circuit and the nature of the sand required.

In an application where there is a long feed curve (ie X-0mm), then vertical shaft impact (VSI) crushing is the preferred method. Where the feed fraction is shorter (ie X-Y) then high-speed compression crushing can be applied. Table 2 shows the parameters for selection of a suitable crusher.

Key criteria in selection of crushing equipment, which are heavily related to final applications like concrete, are:

- Product quality.
- Consistency.
- Yield.
- Operating costs.
- Filler generation.

QUALITY PROCESSES THE KEY

The correct source rock and correct crushing and screening process are key factors in the successful production of manufactured sand. The choice of crushers and screeners depends on the feed material and required end-product use, eg ready mixed concrete, mortar sand, asphalt sand, etc.

Metso Minerals believes that manufactured

sand will play an increasing role in the future because the predictability of the end product, in terms of particle shape, gradation and moisture content, will lead to potentially big savings and earnings.

For the aggregate producer, less waste material will be produced and a high value sand will increase sales potential. For the concrete manufacturer, savings in cement will be a big motivator. High levels of predictability will also lead to lower costs due to reduced rejection rates.

It is clear that the most suitable replacement for natural sand - a product created by the great forces of nature, albeit in a random process - is a product created by an industrialised and repeatable process. •

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TABLE 2

APPLICATION: CONCRETE/MORTAR						
Sand requirement	Rounded cubical shape					
	Minus 5mm	Minus 12.5mm	Minus 25mm	Pea gravel	12.5-5mm	25-5mm
Soft rock*	Barmac B-Series					
Medium rock**						
Hard rock***						

APPLICATION: CONCRETE/MORTAR						
Sand requirement	Angular cubical shape					
	Minus 5mm	Minus 12.5mm	Minus 25mm	Pea gravel	12.5-5mm	25-5mm
Soft rock*	Barmac B-Series			HP/GP/Barmac VI		
Medium rock**				HP/GP/Barmac VI		
Hard rock***				HP/GP		

APPLICATION: ASPHALT						
Sand requirement	Angular shape					
	Minus 5mm	Minus 12.5mm	Minus 25mm	Pea gravel	12.5-5mm	25-5mm
Soft rock*	Barmac B-Series	Barmac VI	Barmac VI	HP/GP/Barmac VI		
Medium rock**		Barmac B-series			HP/GP	
Hard rock***		Barmac B-series			HP/GP	