

# Effect of Admixtures in Concrete Containing Manufactured Sand

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## ABSTRACT

*This paper investigates the results that varied water cement ratios and superplasticiser wear concrete containing manufactured sand as a full replacement for natural sand. because of current levels of construction in land there is Associate in Nursing ever decreasing convenience of natural sands acceptable to be used as a fine mixture in concrete manufactured sands that unit of measurement a by-product of rock crushing operations offer a viable resolution to the declining convenience of natural sands. However, the unit of measurement sort out drawbacks to the use of manufactured sand, notably the poor workability and finish obtained. This could be caused by the High fines content.*

## 1. Introduction

Concrete has been around for many centuries, the first known use of a material resembling concrete was by the Minoan civilization around 2000 BC. During the early stages of the Roman Empire around 300 BC the Romans discovered that mixing a sandy volcanic ash with lime mortar created a hard water resistance substance which we now know as concrete. The predominant type of cement used in modern concrete is Portland cement, other types of cement available include; Blended cement, which is similar to Portland cement but may contain materials such as fly ash slag or silica fume; High early strength cements, which as the name suggests gains strength a lot quicker than Portland or blended cements; Low heat cements, used when limits are placed on the heat of hydration of the concrete; Shrinkage limited cements; Sulphate resisting cements; Coloured cements; Masonry cement [1].

Portland cement is made by mixing calcium carbonate commonly found in limestone or chalk and silica, alumina and iron oxide found in clay or shale. The two ingredients are ground and mixed together in either a dry or wet state depending on the characteristics of the rocks being used. The mix is then placed in a kiln at temperatures as high as 1400 degrees Celsius, at this temperature the two rocks fuse together to form clinker. The clinker is allowed to cool and gypsum is added at around 1 – 5 percent. The mix is then ground to the required fineness and distributed to concrete batch plants. Portland cement derives its name from the Portland limestone because of the close resemblance of the finished concrete to the Portland Limestone. Concrete is one of the most popular materials for construction owing to the fact that it can be cast into just about any shape, it has good compressive strengths, is readily available just about anywhere and is relatively cheap in comparison to other materials available for construction, such as steel or fibre composites. Concrete is made from a mixture of cement powder coarse and fine aggregates, normally sand and crushed rock and water. It can be either mixed in a hand mixer or by a large batch plant [2].

## Aggregates

Aggregates were first considered to simply be a filler for concrete to reduce the amount of cement required. However it is now known that the type of Aggregate used for concrete can have considerable effects on the plastic and hardened state properties of concrete. Aggregates can form up to 80% of the concrete mix so their properties are crucial to the properties of the concrete. Aggregates can be broadly classified into four different categories, they are heavy weight, normal weight, light weight and ultra-light weight aggregates. However in most concrete practices only normal weight and light weight aggregates are used. The other types of aggregates are for specialist uses, such as nuclear radiation shielding for heavy weight concrete and thermal insulation for light weight concrete [3].

Types of aggregates commonly used include natural sands and gravels, crushed rocks and manufactured aggregates. Natural sands and gravels are normally sourced from stream beds, dunes, alluvial deposits or marine deposits. Crushed rocks have an advantage over other aggregates in that their size may be specified by using different size screens when the rocks are crushed. Rock types used for crushed aggregates include igneous rocks such as basalt, diorite and granite; Sedimentary rocks normally used as aggregates are lime stone but occasionally some sandstone is used; and metamorphic rocks are rarely used due to the highly variable nature of the mineral composition of these rocks [4].

## 2. Literature review

The Concrete Association of India's (CAI) guide to Concrete Construction, states that the shape and texture of aggregate particles has an important influence on the workability of freshly mixed concrete, and hence may affect the water demand and the water cement ratio. The use of manufactured sands in concrete causes the concrete to have very poor workability. This is caused by the irregular particle shape of the manufactured sands. The water required for a given degree of workability (slump) is directly related to the void space in the aggregate. When the void space is high, the water requirement necessary for a given workability will also

be high. And the strength of the concrete will also be low unless additional cement is added. The void content of manufactured sand is generally higher than that of natural sand. The higher fines content of manufactured sand has significant effects on the workability and the strength of concrete. The CAI's Guide to concrete construction states that aggregate combinations with excessive amounts of sand or excessively fine sands may produce uneconomical concretes because of the larger surface area of the finer particles. Hudson (1999) reported that "Concrete manufactured with a high percentage of minus 75 micron material will yield a more cohesive mix than concrete made with typical natural sand. Hudson also reported that although the compressive strength and the workability may be superior to natural sand, the finish of the concrete containing manufactured sand is still a major drawback to its use [5].

In order to overcome the negative impacts that manufactured sand has on the workability plasticisers may be used to improve the workability and finish of concrete mixes. The use of a New Generation Admixture for Improvement of Concrete with manufactured sands concluded that through the use of a medium-range water reducing admixtures, incorporating Polycarboxyate technology, a harsh concrete mix was made more workable, cohesive and easier to place and finish. The manufactured sand to be used in this project has been sourced from Wagners and is made using the patented 'Great Divide' Sand Separator. This machine seen in figure 1 is designed to greatly reduce the amount of fines (< 75microns) present in the manufactured sand [6].

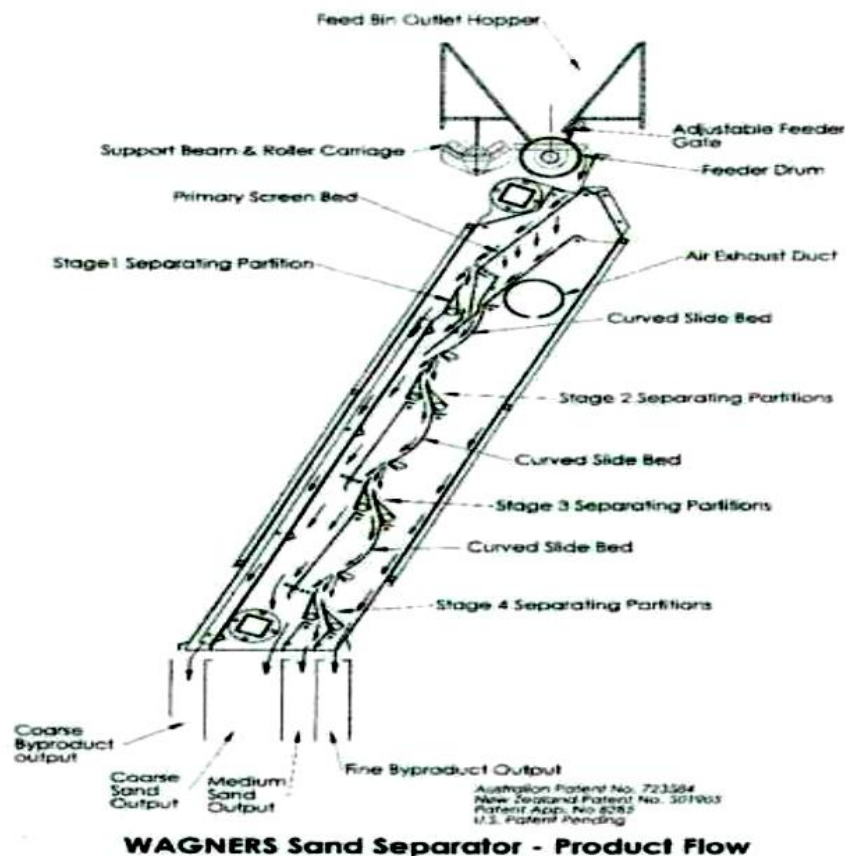


Figure 1: Schematic of the "Great Divide" Sand Separator showing the separation of fines in Manufactured Sand.

### Admixtures

Admixtures are substances which are added to the concrete mix to give it more desirable properties. Admixtures can be classified into a number of different categories. They are [7]:

- Air entraining Agents
- Accelerating Agents
- Retarders
- Water Reducing or Plasticisers
- Superplasticisers
- Bonding Admixtures
- Water Repelling Agents
- Pigments
- Porefillers
- Pozzolans

Each of these different admixtures has a different effect on the properties of fresh and hardened concrete. A superplasticiser will be used in this project because of its ability to dramatically increase the workability of fresh concrete with minimal effect on the overall strength of the concrete [8].

Water reducing plasticiser has a detergent like property which is referred to as a surface active agent. These substances carry an unbalanced charge of electricity and when put into water will migrate towards the surface of the water with the electrically charged end sticking into the water whilst the tail is out of the water [9].

### 3. Experimental methodology

In order to effectively analyse the effects that the manufactured sand has on the fresh and hardened properties of concrete, a number of different trial mixes have been made. These trial mixes are varied in water cement ratios and the percentages of plasticiser added to the concrete mix. The plasticiser chosen for this project was superplasticiser manufactured by Chemical House; this plasticiser was chosen for us in this project for its ability to dramatically increase the workability of the fresh concrete mix. The recommended dosages for the superplasticiser was a range of 0.4 to 1.5 percent for conventional concrete mixes, however it was expected that for this project larger dosages of plasticizer would be required to achieve a suitable workability. The main objectives of the trial batches were to [10]:

- Determine if a suitable workability and strength can be achieved in concrete containing manufactured sand as a complete replacement for natural sand;
- Determine what percentage of superplasticiser is required to achieve a suitable workability for concrete containing manufactured sand;
- Determine the rate of strength gain for the concrete containing manufactured sand with and without superplasticiser;

### Aggregates

To ensure consistency of aggregates all of the aggregates have been sourced from Wagners. To ensure a consistent quality and grading so that alterations were not required for the mix, enough manufactured sand to complete all of the mixes was sourced at the beginning of the testing phase. The manufactured sand used came from Wagners Malloo quarry, where the manufactured sand is produced from the byproduct of blue metal crushing operations. In order to design the concrete mix the aggregates properties had to be analysed. In order to do this a number of tests were carried out on the concrete, they were; sieve analysis, bulk density, dry density and moisture content. All of the aggregate tests were done in accordance with IS 2386 [11].

Due to the increased surface area of the fines, increased amounts of water and cement will be required to achieve target workability's and strengths. The higher amounts of fines and the irregular particle shape of the manufactured sand can also be seen in figure 2. The irregular particle shape also has a negative impact on the workability of the concrete due to the increased amount of voids created in the concrete. However an irregular particle shape may produce a stronger concrete mix than a mix made with rounded particles as the aggregate will interlock better with the other aggregate and the cement paste [12].



Figure 2: Comparison of Manufactured Sand (right) and Natural sand (left)

### Concrete Mix Design

A number of different trial mixes were decided to be assessed; firstly the water cement ratio of the trial mixes were altered to assess the properties of the concrete containing 100 percent manufactured sand and no plasticiser. Initially it was decided to try and achieve a medium strength concrete mix around 25 Mpa. From the study guide this gave a target strength of around 32 Mpa. This target strength corresponded to a water cement ratio of 0.65. After trialling this mix it was discovered that the mix achieved a reasonable workability without the use of a superplasticiser. In the next mix it was

decided to try and reduce the workability by reducing the water cement ratio to 0.5. This mix had a much reduced workability than previous but further reduction of the workability was necessary before the superplasticiser. The next mix trialled had a water cement ratio of 0.4 and exhibited very poor workability. This mix was adopted as the mix which would be used for the addition of superplasticiser. This was also adopted as the water cement ratio of the natural sand control mix [13].

The target grading adopted for the aggregate was chosen from a previous study done by a research student, on manufactured sand so that some comparisons might be drawn between the two different studies. The adopted target grading is seen in table 1. The aggregate blend was developed using Rothfuchs methods for two or more aggregates for the mixes with manufactured sand and for the natural sand mix. This blend was later checked using a spreadsheet program which showed that the actual mix quantities provided a grading very close the target grading.

The aggregate cement ratios were selected by using the tables provided in (chapter 3 pp3.10-3.11) of the concrete technology study book. The different trial mixes are summarised in table 3.3, trial mix 7 was the natural sand control mix. Each trial mix required 15 small concrete cylinders, (100mm diameter 200mm high) for measuring the compressive strength of the concrete and 2 large cylinders (150 mm diameter 300mm high) for the indirect tensile test [14].

**Table 1: Target Grading**

Sieve Size (mm)	Percentage Passing
26.5	100
19	99
13.2	80
9.5	65
6.7	52
4.75	48
2.36	42
1.18	35
0.6	22
0.3	10
0.15	3
0.075	2

**Table 2: Summary of Trial Mixes**

Mix Number	WC ratio	AC ratio	% plasticiser
1	0.65	5.2	0
2	0.5	4.1	0
3	0.4	3.3	0
4	0.4	3.3	0.88
5	0.4	3.3	1.77
6	0.4	3.3	2.36
7	0.4	3.3	0

**4. Results analysis**

As discussed earlier, the main objectives of this project were to:

- Determine if a suitable workability and strength can be achieved in concrete containing manufactured sand as a complete replacement for natural sand;
- Determine what percentage of superplasticiser is required to achieve a suitable workability for concrete containing manufactured sand;
- Determine the impact that the superplasticiser has on the strength of the concrete;
- Determine the rate of strength gain for the concrete containing manufactured sand with and without superplasticiser.

**Aggregate Analysis**

The results of the sieve analysis as expected showed that manufactured sand has considerably larger amount of fine material than the natural sand. The grading of the natural sand and the manufactured sand are extremely dissimilar and for this reason the aggregate blend for the natural sand mix will be different to the aggregate blend for the manufactured sand mix.

**Fresh Concrete Properties**

The results of the slump tests carried out on the fresh concrete gave a good indication of the workability of the concrete; however the slump test is limited in its applications. A better indication of the workability is given from the Compacting Factor tests and from the Vebe tests. A summary of the fresh concrete tests can be seen in table 3 [15].

Table 3: Summary of Fresh Concrete Properties

Mix Number	WC ratio	% plasticiser	Slump	Compacting Factor	Vebe
1	0.65	0	160	0.992	1:23
2	0.5	0	70	0.967	1.81
3	0.4	0	22	0.890	5.19
4	0.4	0.88	46	0.969	2.92
5	0.4	1.77	104	0.978	1.4
6	0.4	2.36	174	0.993	1.29
7	0.4	0	185	0.993	0.64

The results obtained from the slump tests shows that as the water cement ratio or the percentage of plasticiser was increased the slump of the concrete also increased. This was to be expected. However the slump that was obtained was considerably less than what would have been expected from a comparable mix which contained no manufactured sand and only natural sand.

The trial mixes which had manufactured sand were also a lot more difficult to finish and a lot more time was required to

trowel the mixes to achieve a decent surface finish. Even with the addition of a superplasticiser, it still required a large amount of trowelling to achieve an acceptable surface finish. The difficulty in achieving a smooth finish with the manufactured sand can be attributed to the irregular particle shape of the manufactured sands. The difference in the surface finish obtained with a manufactured sand (left) mix and a natural sand (right) mix can be seen in figure 3.



Figure 3: Comparison of surface finishes

The results of these slump tests appear to show that a good workability is achieved with a water cement ratio of 0.65, however although the slump was high the concrete was still quite sticky and was not as easy to place as a concrete with a slump in that region should be. This difficulty is caused by the higher fines content of the manufactured sand. A better indication of the workability of the concrete mixes can be gained from the Vebe tests. This test shows that although the slumps were reasonably similar for mixes 1, 6 and 7 (control Mix) the time taken on the Vebe consist meter for the

manufactured sand mixes is almost twice as long as the time taken for the natural sand control mix.

#### Compressive test results

The hardened properties of the concrete have been measured at ages 3, 7, 14, 21 and 28 days, this has been done to determine the rate of strength gain of the concrete. The compression tests are summarised in table 4 below. Due to restrictions on the availability of mixing equipment in the concrete lab a number of mixes had to be tested at 2 and 4 days instead of 3 days of age.

Table 4: Summary of Compression Tests

Mix Number	WC ratio	% plasticiser	AGE				
			3	7	14	21	28
1	0.65	0	16*	25	30	33	35
2	0.5	0	29	39	44	46	48
3	0.4	0	32*	45	48	48	48
4	0.4	0.88	42**	43	47	51	54
5	0.4	1.77	37	47	53	56	60
6	0.4	2.36	31*	51	59	62	63
7	0.4	0	29	43	47	48	49

Note: \* indicates the specimen was tested at 2 days of age instead of 3 days of age

\*\* indicates the specimen was tested at 4 days of age instead of 3 days of age

The results from the compression tests as expected showed that as the water cement ratio was increased the strength of the concrete declined; These graphs clearly show that the higher the water cement ratio the lower the compressive strength. Comparing mixes three and seven shows that a manufactured sand mix with no plasticiser is capable of a similar strength of a natural sand mix. But the manufactured sand mix was able to reach its maximum strength a lot faster than the natural sand mix was able to. This discovery could have significant implications on the uses of manufactured sands in the construction industry.

## 5. Conclusions

By using large amounts of water in the concrete mix manufactured sands are capable of achieving a suitable workability and also achieving the target strength. However the amount of time required for achieving a suitable finish on the concrete is still a major drawback to its use in the construction industry. With the addition of a superplasticiser a

concrete mix containing manufactured sand is capable of not only achieving a workability similar to that of natural sand, however to achieve this workability, dosages as high as 2.36 percent were required. The additional cost of these large amounts of superplasticiser in the concrete mix makes the manufactured sand concrete mix less economical to produce than a natural sand control mix. However with the declining availability of natural sands suitable for use in concrete, the use of concrete mixes containing 100 percent manufactured sand or high percentages of manufactured sands in the aggregate blend may become a lot more common.

The addition of superplasticiser into a concrete mix not only improves the workability of the concrete mix but also the strength of the concrete mix. When large amounts of plasticiser were added the strength improved by around 30 percent on the mix without plasticiser, however the rate of strength gain of the concrete mix is lowered considerably when the plasticiser is added.

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