# Use of Duramicrosilica to produce durable and waterproof concrete structure

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## 1. INTRODUCTION

**Duramicrosilica** is an additive that improves properties of both strength and impermeability of hardened concrete. **Duramicrosilica** reacts with lime / calcium hydroxide that forms during the hydration of cement. This creates an increased amount of CSH (Calcium Silicate Hydrate) crystals. Thus the content of weak calcium hydroxide decreases, while the content of CSH crystal, which provides strength, impermeability and durability, increases. These are the main effects of producing waterproof and durable concrete.
Often water reducing admixture like Superplasticiser may have to be used in conjunction with **Duramicrosilica** to produce workable concrete.
Most of the times, concrete of underground structures are liable to be attacked by leaching of calcium hydroxide or by ingress of harmful, disruptive substances , such as Sulphates or Nitrates. Since **Duramicrosilica** reduces the amount of soluble calcium hydroxide, the leaching is reduced. So, **Duramicrosilica** in concrete in underground structure enhances the resistance to chemical attack. **Duramicrosilica** is a superb material to produce high strength, highly impermeable and durable concrete in underground structure.

## 2. STANDARDS

| Properties /parameters | USA ASTM C 1240-99 | India IS 15388-03 | Canada CSA A 23.5.98 | Australia AS 3582 | Japan JIS A 6207:00 | Europe CEN pr. EN 13263 : 99 | Duramicrosilica Typical Results |
|---|---|---|---|---|---|---|---|
| Silica($SiO_2$) % min | 85 | 85 | 85 | 85 | 85 | 85 | 89.2 |
| $So_3$ % max | - | - | 1.0 | 3 | 3 | 2 | - |
| CI % max | - | - | - | - | 0.1 | 0.3 | - |
| L.O.I. % max | 6 | 6 | 6 | 6 | 5 | 4 | 0.2 |
| Specific Surface | - | 15 (optional) | | | 15 | 15-35 | - |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Area: sq. mt./g minm | | | | | | | |
| Pozzolanic Activity Index, % min | 85 at 7d, accelerated | 85 at 7d, accelerated | 85 | - | - | 100 at 28d | 105 |
| Retained on 45µ sieve, % max | 10 | 10 | 10 | - | - | - | 3.0 |
| Moisture content, % max. | 3 | 3 | - | 2 | 3 | - | 0.9 |

Microsilica was first tested in Norway in 1947 with a variety of potential application benefit. The last twenty-five years have seen a rapid growth in the use of micro silica concrete to the present level of over 6 million tons/year.

Microsilica concrete is especially beneficial in areas where the structures are subjected to severe environmental attack. This is true for hazardous ground condition, marine exposure, chemical attack or physical deterioration such as abrasion or erosion. The concrete can also be designed to give very high strength up to M 1200 grade if suitable superplasticiser is used. In fact high performance concrete can be produced with much improved workability, pumpability, cohesion and adhesion, reduced bleeding and superb surface finish if Duramicrosilica is incorporated in the concrete mix after having it designed properly. High resistance to chemical attack and very high degree of impermeability with extraordinarily increased strength of concrete increase the durability factor manifold.

Initially the use of microsilica was meant to replace cement, due to its very pozzolanic reactivity, but as more data came in from testing and fieldwork, the material became an additional cementitious component giving increased performance in both the fresh and hardened states.

Currently there are over a dozen of standards or codes of practice around the world that allow the use of microsilica in cement and concrete.

## 3. PRODUCTION OF MICROSILICA :

There are mainly two ways of producing Microsilica:

a) Microsilica is produced at a very high temperature up to 2000°C, when quartz is reduced to silicon or ferrosilicon metal in an electric arc furnace. During this process, silicon monoxide gas forms besides formation of metal. Such gas reacts with oxygen in the upper part of the furnace and gets stacked. As soon as cooling starts, it condenses into physical particles of microsilica. Bulk density of such material is around 200 kg/cubic metre.

b) Microsilica is also produced by burning black coloured rice husk into white coloured high purity silica. Such silica is highly reactive and is used as microsilica. Our Duramicrosilica falls under this category. The following paragraphs look at the properties of microsilica.

**Bulk Density:** Microsilica is a very fine particle like particle of smoke and it is very hazardous to handle them. This is known as undensified microsilica. When it is densified, it has a very fine

granular appearance. This form is not as 'dusty' as undensified micro silica. It is much more user friendly in terms of handling. Its uses are seen in precast industries and Ready Mix Concrete plant. Bulk density of undensified one is typically from 200 to 350 kg/cum and that of densified one is around 500 to 700 kg/cum.
Palletised microsilica is around 1000 kg/cubic metre. Slurry of microsilica is also found to be easy handling. In such case around 50% microsilica water slurry is prepared and it is very easy to handle.
Due to its very fine nature, there is a need to handle it with proper mask of nose and mouth, as normally standard pre-caution is required for every powder product like cement and other dust.

**Silicon Dioxide ($SiO_2$):** In microsilica this is the reactive component (amorphous). It combines with the calcium hydroxide, released during hydration, to form gel product of **calcium silicate hydrate**. This is called pozzolanic reaction and it gives very high impermeability and strength. Though all standards stipulate a minimum level of 85% but with a level below this can give good results. This requirement is stipulated to minimum pozzolanic effect. It should also be remembered that lower the $SiO_2$ content, the higher content of other, probably deleterious materials. A good value for microsilica would be around 90% and above.

**Loss on Ignition (LOI):** Loss on ignition (LOI) is a significant component LOI indicates how much organic contaminant is present in microsilica. Higher the value less is the action of plasticiser/superplasiciser with microsilica. Lower the value of LOI is highly recommended all the time typically less than 3%.

**Specific surface area:** The finer the pure spherical particle, the more reactive surface is available to the pore water containing calcium hydroxide. The finer the material, higher the $SiO_2$ content and the greater the reaction and higher would be the performance of the concrete. Therefore a moderate lower level is given with a higher level equal to the highest value in the standard.

**45 micron sieve residue:** Such method gives rise to the determination of the agglomerated particles or crystalline material. In fact such residue should be less than one percent but ASTM & BIS mention 10% max.

**Moisture:** Microsilica should not contain more than 3% moisture. More than this value would probably cause formation of lumps if the material is heavily stacked. Under pressure it becomes solid mass and it would be difficult to disperse them properly.

**Pozzolanic Activity:** This is the most important property of Microsilica. It is a measure of the reactivity of 90% OPC and 10% Microsilica in 100% OPC. Due to the very high reactivity of the Microsilica, it is not likely to fail this test.

## 4. USAGE IN CONCRETE

Microsilica is usually added as an additional (supplementary) cementitious material at a (dry) percentage of the original cement content. In most cases the amount of microsilica can be added to the cement for the purpose of calculating the water-binder ratio, although a correction factor is

sometimes applied for the purpose, - reference should be made to the appropriate national or international standard.
The percentage of microsilica added will vary with the type, quality and performance of the required concrete. The starting point of any trial mixes for a particular application would be within the ranges shown in the Table below.

| Application | Range, percent by weight of cement |
|---|---|
| Pumping aid | 2 to 3 |
| Improved quality | 4 to 7 |
| Strength | 7 to 15 |
| Underwater | 12 to 15 |
| Sprayed | 8 to 12 |

The dosage and effectiveness of the microsilica action will depend on all the same factor that affect an ordinary concrete – cement reactivity, coarse aggregate type and strength, fine aggregate quality, type and dosage of plasticiser or superplasticiser, etc. this is the reason that trial mixes should always be undertaken to ensure compatibility and end performance. It is not sensible to merely add a few bags of micro silica into a ready-mix truck and expect the material produced to be the strongest and most durable concrete ever made.
Mixing procedure may vary in line with the production facility, but the general rule is to add the microsilica to the concrete mix as soon as possible and mix thoroughly, to ensure maximum dispersion within the concrete. Most microsilica concretes incorporate a plasticiser or superplasticiser to aid this dispersion.
It should also be remembered that adding 35 to 40 kg of micro silica to a mix will be the same as adding an extra 200 kg of cement in terms of cementitious value. As such the mix design will need to be modified to take this effect into consideration with regards to workability, placing and finishing. The 'rule of thumb' is to cut back the fine aggregate by about half the percentage of the microsilica being added. Again trials should be conducted to achieve the required rheology. This effect does mean that under dosing or overdosing can be spotted fairly easily. If the mix has been correctly designed for the micro silica addition then a 'no dose' or 'low dose' will give a harsh and stony mix. An 'over dose' or 'double dose' will give a very stiff, 'fatty' mix.

## 5. FRESH CONCRETE PROPERTIES AND HANDLING

The superfine nature of microsilica particles means that the concrete will be more cohesive than standard OPC mixes and as such are often viewed as having lower workability – in terms of slump value. However, the microsilica particles, being perfectly spherical, act as ball lubrication in the mix and this will give a better 'place-ability' for an equivalent slump. In order to prevent the addition of the normal 'on-site plasticiser' (water) when microsilica concrete is first delivered to a new site, a superplasticiser is often incorporated to give a high workability while keeping the correct water-binder ratio.
Standard placing, compaction and finishing techniques are perfectly acceptable for microsilica Concretes, although the material does lend itself to the more advanced process such as superflat self-levelling, large-scale laser screed work and earlier powerfloating.
The high cohesion and stability of the mix means that micro silica concretes are most suitable for spraying, pumping and under water placement. Sprayed concrete will have lower rebound,

greatly reduced dust and higher build characteristics. Pump mixes will go further and higher than standard pump designs and at reduced pressures. Microsilica concrete can be placed underwater, by standard tremie techniques under most normal conditions, without the use of extra additives.
Due to the void filling action, which gives a higher cohesion to the mix, fresh microsilica concrete will exhibit no bleeding. This means that the plastic concrete must be properly cured as soon as finishing work is completed. Standard curing actions-as in BS 1881 for instance-can be used. The addition of microsilica to concrete can give high performance, but it will not protect it from the ‘human effect’. Microsilica concrete is just as susceptible to poor workmanship as ordinary concrete and all normal site operations should be performed to the optimum requirement.

## 6. HARDENED CONCRETE PROPERTIES

The superfine size of the microsilica particles which is 100 times finer than cement, combined with the very high silicon dioxide content, gives a powerful pozzolanic effect. The size of the particles means that with average dosages of about 40 kg, there will be approximately 1 sq. km. of surface area capable of reacting with the calcium hydroxide that is formed as the cement hydrates. This means that the microsilica will have an earlier effect than other types of pozzolans. However, this should not detract one from using pulverized fuel ash or ground granulated blast furnace in combination with microsilica. Indeed, the triple blend combination effect has shown to produce very high performance concrete.
The pozzalanic reaction of the microsilica increases the calcium silicate hydrates in hardening concrete. There is a distinct change in the refinement of the pore structure, giving less of the capillary pores and more of the finer gel pores. This increase in the calcium silicate hydrates and the reduction in the capillary pores give Micro Silica concrete its two major benefits- increased strength and increased impermeability. The dual effect gives the concrete increased resistance to physical attack; abrasion, erosion and impact damage; and to chemical attack; water penetration, sulphates, chlorides, organic materials and acids.
It is the increased resistance to sulphates and chlorides that has led to major use in the Arabian Gulf, where the chemical attack and temperature have a rapid deteriorating effect on concrete and reinforcing steel. In some cases buildings less than 10 years old have had to be demolished. Life time expectation, on buildings currently under construction, is upwards of 50 years now. With the capacity of using high strength microsilica concrete (over 80 MPa) taller buildings are also coming up in the Gulf. Currently the tallest building is over 320 m.
It is these same characteristics which are leading more projects in India to specify and use microsilica concrete. Higher strengths can be achieved with greatly improved durability.