MasterMatrix LF compensates 50-70Kg of fines in concrete

This new product from Master Builders Solutions improves the stability and homogeneity of concrete with reduced fines or paste

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Introduction

The depletion of natural resources is currently a topic of serious concern globally. As concrete production continues to expand to accommodate population growth and increased urbanization, the construction industry is called upon to ensure the responsible use of the natural resources. Avoiding waste and utilizing locally available materials to minimize transportation distances will contribute to the global challenges related the environment and preservation of the planet.
MasterMatrix LF is a new stabilizer which has been developed by Master Builders Solutions to **improve concrete stability and homogeneity.** A dose of only 1 to 1.5 Kg of MasterMatrix LF can compensate for 50 to 70Kg of fines (particles with a diameter < 250 µ) per m^3 of concrete or alternatively for 30-40 liters of paste. The "LF" in the name means "low fines".
It is a generally accepted fact that "good" concrete requires a certain level of fines to achieve the desired quality, i.e. a homogeneous state which is easy to pour, pump and finish. Concrete which lacks fines is prone to segregation and poor pumpability. Consequently, application and finishing are more complex and take longer. Traditionally, the ideal level of fines in concrete has been achieved from a combination of components, namely cement, sand, limestone filler and supplementary cementitious materials (SCMs) such as fly ash and slag. Concrete today often lacks the necessary fines content for several reasons:

a. The availability of fly ash and slag is in constant decline
b. Cement dosage is kept at a minimum to reduce the associated CO_2 emissions.
c. The availability of high-quality sand is diminishing, forcing concrete producers to find ways to use lower quality but easily available sands.

MasterMatrix LF ensures the stability and homogeneity of the concrete in situations which, under normal circumstances it would not be optimal:
1) **Fly ash scarcity** forces concrete producers to increase the cement content of concrete mixes with the corresponding increase in CO_2 emissions and costs.

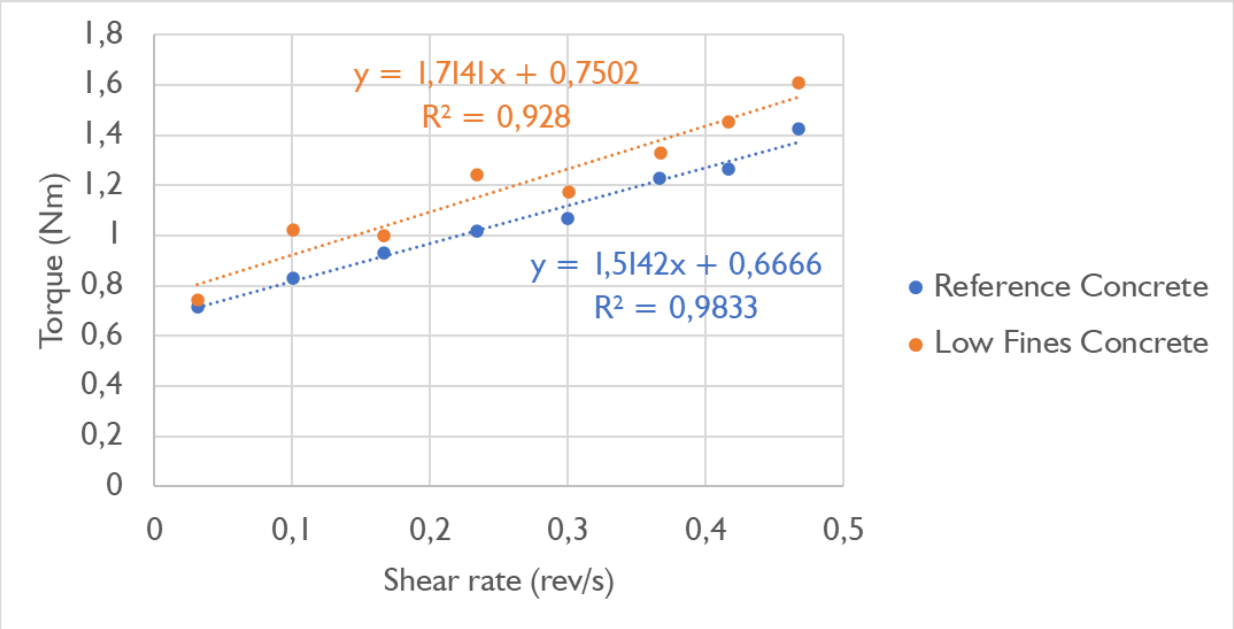
2) **A lack of fines in sand**, either because the locally available sand has intrinsically low fines content, or because it has been heavily washed. Under these circumstances, concrete producers have the choice of blending in more expensive sand types, transported from further away, or increasing the cement content. Both solutions would negatively impact sustainability targets and increase costs.
3) **A scarcity of fines** (fly ash or limestone filler) in **Self Compacting Concrete** is corrected by the overdosing of cement. Another alternative would be to invest in a silo for the increased use of filler. MasterMatrix LF avoids the need for more cement or for more filler, a clear cost advantage.
4) **The use of low-clinker cements** is increasing and is being driven by sustainability targets. In order to achieve the specified compressive strengths, a further reduction in the water content is a trend which is being increasingly observed. Under these circumstances, the volume of paste, considered as the total amount of water and fines, will decrease which negatively impacts the handling, placing and pumping qualities of the concrete mix. MasterMatrix LF has been designed to ensure the stability of low-clinker concrete with reduced water content.

MasterMatrix LF: practical cases
To prevent the instability of the concrete when the fines content is limited, MasterMatrix LF provides the desired plastic viscosity equal to or better than that of reference concrete. Two scenarios were tested where the introduction of MasterMatrix LF was used to compensate for the reduced fines content.
Scenario 1
In this scenario, 30kg/m^3 of limestone filler were replaced by the corresponding volume of sand. In the reference concrete, with a cement dosage of 270kg/m^3 and 8% of sand particles below 125µ, the total fines content is 374kg/m^3. In the Low Fines Concrete, with limestone replaced by the same volume of sand, a total amount of fines of 346 kg/m^3 was achieved: a reduction of 31kg/m^3 compared to the reference concrete. The table below details the concrete composition and the results of the tests carried out on the concrete mixes in their fresh state.

	Reference Concrete (kg/m^3)	Low Fines Concrete (kg/m^3)
CEM II/B-M 42,5 R	270	270
Sand	925	955
Crushed Aggregates D_{max} 20mm	1045	1045
Limestone Filler	30	--
Water	155	155
Superplasticizer	1,7	1,5
MasterMatrix LF	--	1,0
Density (kg/m^3)	2457	2447
Initial Slump (mm)	200	200
Initial Air Content (%)	2,3	3,3

Slump at 30' (mm)	120	130
Air at 30' (%)	2,7	3,8

In the low fines mix, the introduction of MasterMatrix LF provides the desired stability with a slight increase in plastic viscosity. This rheological parameter was measured using an EBtV rheometer from Schleibinger Geräte AG and reading the torques at different shear rates. The interpolation of the data and processing was carried out using a Bingham by Reiner - Riwlin model and is shown in the graph and the table below.



	Reference Concrete	Low Fines Concrete
Yield Stress (Pa)	157	204
Plastic Viscosity (Pa*s)	55	64

Both concrete mixes do not show any apparent differences and are quite similar, as the photos indicate.

Reference Concrete

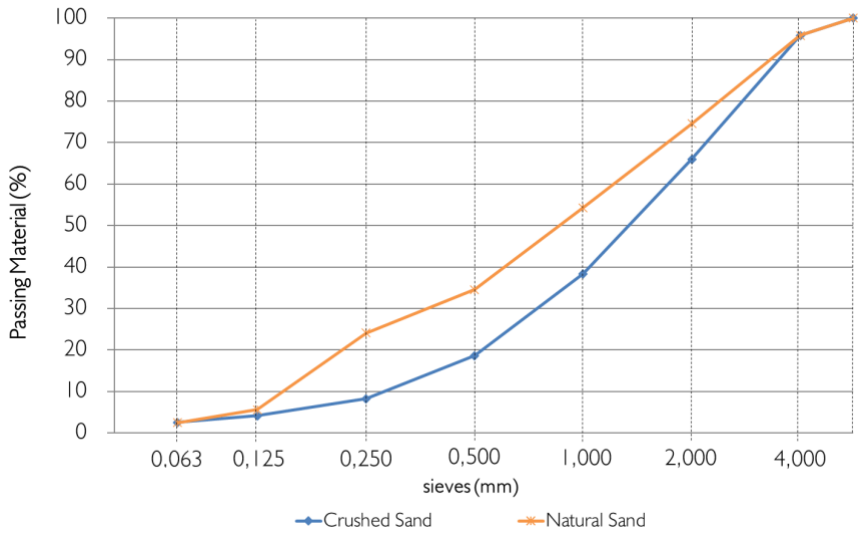
Low Fines Concrete

The comparison was completed by measuring the compressive strength: after testing the workability retention, 6 cubes of 15x15x15 cm were cast for each concrete mix, which were demolded after 24 hours: two were immediately tested, while the other four were cured at 20°C and R.H. > 95%. They were then tested after 7 and 28 days respectively. The table below shows that the compressive strength of both concrete mixes is very similar as we would expect because both mixes contained the same dosages of cement and water. We can conclude that MasterMatrix LF does not affect the hardened properties of concrete.

	Compr. Strength at 24h (MPa)	Compr. Strength at 7d (MPa)	Compr. Strength at 28d (MPa)
Reference Concrete	16,6	31,9	37,3
Low Fines Concrete	15,2	28,7	37,5

Scenario 2

The second scenario is based on the situation where concrete producers increase the proportion of crushed sand because of a scarcity of natural sand: this reduces the stability of the concrete. The difference in particle size distribution between the two sands is described in the diagram below. It shows that the crushed sand has a lower content of passing material at the 250 µ sieve.



The modulus of fineness of natural sand is 3.11 whereas it is 3.69 for the crushed sand.
The qualities of MasterMatrix LF as a rheology improver was highlighted by eliminating the natural sand: the composition of both the reference concrete and the low fines concrete with and without MasterMatrix LF (LFC + MasterMatrix LF) is shown in the table.

Kg/m^3	Reference Concrete	Low Fines Concrete	LFC + MasterMatrix LF
CEM II/A-M (V-LL) 42.5 R	320	320	320
Natural Sand	384	--	--
Crushed Sand	384	757	757
Crushed 10	374	376	376
Crushed 20	749	751	751
Water	186	186	186
Superplasticizer	4.0	6.0	6.0
MasterMatrix LF	--	--	1.0
Fines content < 0.125mm	444	382	382
Air (%)	3.6	3.2	4.2

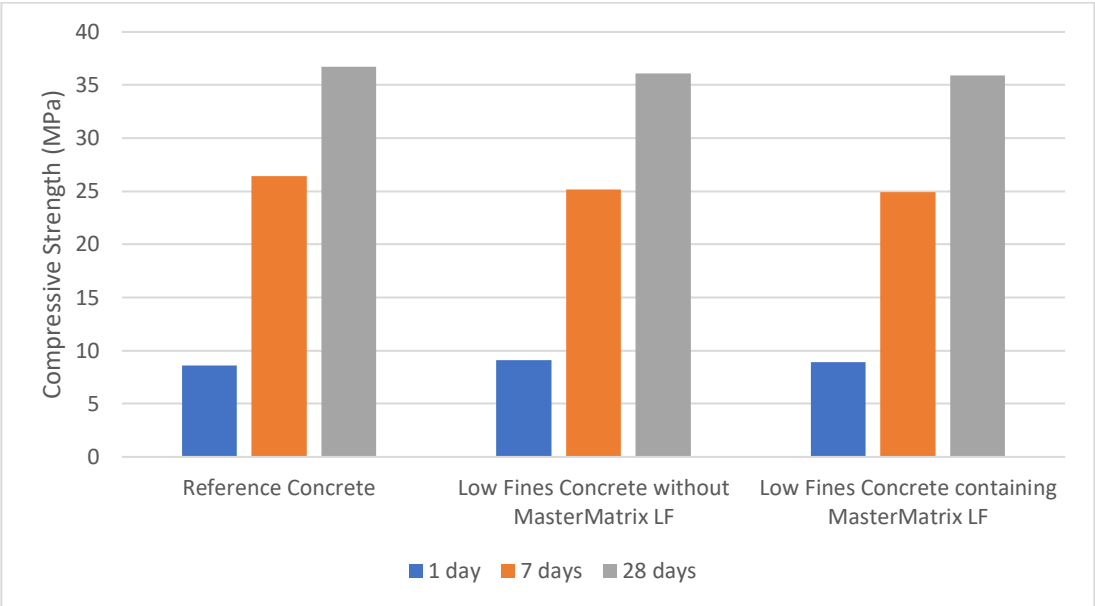
The concrete mixes were analyzed by measuring the initial consistency according to EN 12350-5 (Flow table test) and the entrained air. Moreover, photos were taken to show any segregation or instability. Finally, 6 cubes 15x15x15cm were cast to verify the compressive strength after 1, 7, and 28 days.

Reference Concrete

Low Fines Concrete without MasterMatrix LF

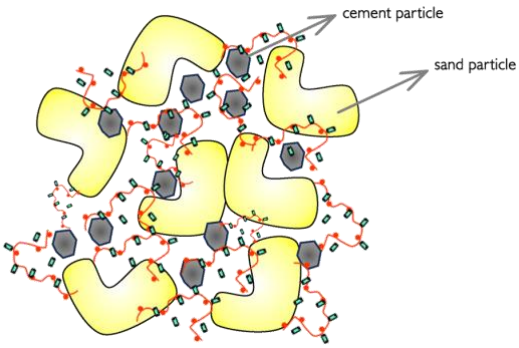
Low Fines Concrete containing MasterMatrix LF

The concrete mixes have almost the same consistency (slump flow ≈ 600mm), but the Low Fines Concrete without MasterMatrix LF bleeds at the border, a symptom of instability: upon the introduction of MasterMatrix LF no paste is released, and overall the concrete appearance is comparable to the reference concrete.
The measured air in the Low Fines Concrete containing MasterMatrix LF was slightly higher than the reference concrete. Still, any excess air efficiently dissipates from the matrix through vibration, which is proven by the matching compressive strengths from the graph below.



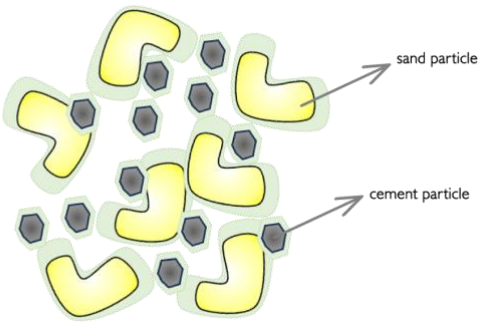
Mechanism of action of MasterMatrix LF
The performance of MasterMatrix LF is ensured by the synergistic combination of two working mechanisms:

1) **Rheology optimization** through engineered polymers that ensure stability and homogeneity with only a slight increase in plastic viscosity. Many conventional viscosity modifying agents, such as cellulose ethers provide homogeneity but have the drawback of a significant increase in viscosity. MasterMatrix LF demonstrates shear-thinning behavior, allowing concrete to flow easily once movement is initiated. Compared to traditional viscosity modifiers, the new molecule creates a network which bridges all particles. This bridging force depends on the shear applied to the concrete. When the shear is low, segregation of heavier particles is avoided by increasing the plastic viscosity of the network. When the shear increases, the network partially loosens to reduce viscosity. In practice, this effect gives concrete the desired rheology throughout the entire production process, from placing to finishing.



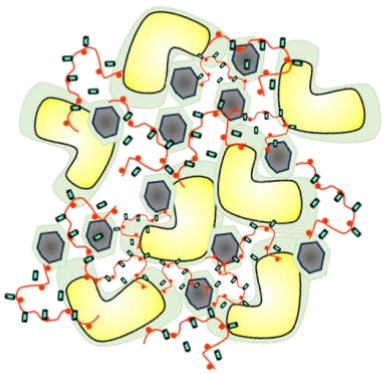
Mechanism part 1 - Network

1) **<u>Tribological effect with friction/energy dissipation</u>**. This lubrication effect functions similarly to mechanical bearings where MasterMatrix LF envelopes the solid particles inside the concrete mix to reduce inter-particle friction and dissipate energy.



Mechanism part 2 – Tribological effect

The picture below shows both mechanisms combined.



Conclusions

MasterMatrix LF is an innovative solution from Master Builders Solutions, to improve the homogeneity and the stability of concrete and ensure excellent pumpability and *placeability* when the materials' grading curve lacks fines. The benefits are multifold and embrace the reduction of CO_2 emissions, the improved utilization of natural resources, lower operational complexity and not to be neglected, reduced costs.