TECHLINE8
FOR THE CONSTRUCTION INDUSTRY

Quality, Efficiency, Sustainability and Available Standards of Dry Mix Mortars

INTRODUCTION

The introduction of dry mix mortar technology in the 1950's revolutionized the construction industry. Since then there has been a rapid adaptation to dry mortar technology in many countries, particularly in western countries. One of the major drivers for the fast growth of dry mix mortar was its very high efficiency which was critical during the industrial revolution of the last century.

Today, the impact of the building and construction industry on the environment is under heavy scrutiny. Dry mix mortar is used in many different applications in the construction of a building and where the sustainability aspect of the material was not a point of main consideration in the past (several other technical and commercial advantages associated with dry mix mortar technology were the centre point), this is no longer the case.

This paper briefly discusses three key sustainability aspects of dry mortar technology which are: durability, quality and efficiency. The extended durability can enable long term performance and low maintenance which is a major consideration for more sustainable buildings. This can also have a huge positive impact on cost savings. The second aspect is the quality and consistency of the dry mix mortars which helps ensure trouble free installation and excellent finishes, contributing to improved living quality. The third aspect is the efficiency of the dry mix mortars which enable optimum usage of the material supporting very high productivity levels: which in turn will save time and therefore cost. The paper will also cite some examples which support the sustainability contributions that can be offered by dry mix mortar.

The paper further discusses the importance of standards in dry mix applications and briefly reviews the European standards for some of the key applications such as cement based tile adhesives, cement renders and external thermal insulation composite systems (ETICS).

HISTORY, DEVELOPMENT AND ADVANTAGES OF DRY MIX MORTAR

Mineral binders such as cement, lime or gypsum have been used as masonry mortars and rendering mortars for more than 8,000 years in the construction of buildings. Until the middle of the last century cement based mortars were prepared by mixing cement, sand and water in the appropriate ratio by hand at the jobsite, referred to as job-site mixing technology. The quality of the job-site mixed mortar depended on the quality of the raw materials and the correct blending ratio which could not be controlled easily. Under these conditions the quality of the mortars produced by job-site mixing technology cannot be guaranteed.
In the 1950's factory pre-mixed mortars commonly known as dry mortar technology were introduced which revolutionized the construction industry. The major advantages of materials made with dry mortar technology are that they are produced in a dry mix mortar plant by mixing together all necessary raw materials such as mineral binders, aggregates and chemical additives including cellulose ethers and redispersible polymer powder. This helps to guarantee the quality of dry mix mortars in order to provide the end user with the same consistency and quality every time.
During the 1950's in Western Europe and particularly in Germany there was a huge demand for new building technologies. The main drivers for these developments were:

1. more efficient construction practices to offset the increase in labor cost
2. mortars suitable for specific applications and
3. increased demand for better quality

The major trends that we observe worldwide which are influencing growth of dry mix mortars are:

– the replacement of the job-site mix practices with mechanization and automation of manufacturing
– changes in transport and application of mortars
– meeting the demands of new construction techniques by modifying the mortars with additives such cellulose ether, redispersible polymer powder or admixtures etc.

The technical and commercial benefits of dry mix mortars are well understood and accepted in the construction industry. The list below provides a summary:

– Improved quality and consistency
– Less storage space
– Ease of handling – just add water
– Very low wastage of material at the site
– Low dust formation
– Ease of application
– High efficiency – faster and quicker construction possible
– Helps ensure application safety and reliability
– Less consumption of cement due to thinner layers
– Optimum use of material
– Special properties possible with additives

IMPORTANT DRY MIX MORTAR APPLICATIONS

Dry mix mortars are used in many different applications in the construction of a building. Some of these applications are universal and some others are specific to certain regions or countries. The key dry mix applications are:

a. Cement based tile adhesives
b. Renders and plasters based on gypsum or cement
c. External thermal insulation composite systems (ETICS)
d. Tile grouts
e. Self leveling underlayments and screeds
f. Repair mortars
g. Brick-laying masonry mortars
h. Cementitious water proofing

SUSTAINABILITY ASPECTS OF DRY MORTAR TECHNOLOGY

The 19th century witnessed the industrial revolution where everything was driven by machines. The next revolution is likely to be an environmental revolution. In the 21st century it will be the environment that drives the way we think and act and sustainability will be the mantra of the century. Sustainability is a broad and complex subject with different components and definitions. From the literature reviewed, the authors have defined sustainability as meeting the needs of the present without compromising the ability of future generations to meet their own needs.

Buildings, infrastructure and the environment are inextricably linked. The building industry is a large producer of waste, and an intensive user of virgin materials and energy.
Thus, improvements in construction practice and design stage throughout the building life cycle can lead to significant environmental benefits. Globally, buildings consume 16 % of the water, and 40 % of the energy used annually; close to 70 % of the sulphur oxides produced by fuel combustion are produced through the creation of electricity used to power houses and offices.

Dry mix mortars are one among many different construction materials that used in construction of buildings. The contributions dry mix mortars can make to improving sustainability have been a topic of in-depth discussions and analysis for a long time. The primary impact of dry mix mortar on sustainability can be summarized into three main areas: durability, quality and efficiency. The section below elaborates upon these in more detail.

Durability

The extended durability offered by dry mix mortars can help support long term performance and low maintenance which is a major consideration when aiming for construction of more sustainable buildings. Offering better durability can also have a huge positive impact on cost savings. Dry mix products can be designed to meet various end-use requirements such as different climatic conditions, temperature variations, different substrates etc. and can therefore be designed to survive different weather conditions. Additives such as cellulose ethers (eg: WALOCEL™ methyl cellulose) and redispersible polymer powders (eg: DLP: DOW™ Latex Powder) can help enhance the performance of tile adhesives, for example. Reducing the maintenance cycle also has a significant positive impact on the overall maintenance cost of a building.

Quality

Dry mix mortars are mostly manufactured in plants which are automated and have good process controls. This helps ensure proper weighing and charging of various raw materials and additives and enables homogeneous mixing. Typically, quality control is done for every batch of dry mortar produced, meaning the quality and consistency of the dry mix mortar can be guaranteed and customers can expect to receive the same quality every time. In addition, since the dry mix mortars are modified with polymers and additives, they offer excellent application properties, helping to ensure trouble free installation and excellent finishes and helping to improve living quality.

Efficiency

One of the most important drivers for the growth of dry mix mortar was its very high efficiency. Using dry mix mortar enables the use of machines for application which can result in huge time savings and more efficient use of material: this in turn supports very high productivity and therefore time and cost savings. Below are some examples of the benefits of dry mix mortars directly linked to sustainability.

Yield of dry mix mortars

Dry mix mortars typically contain special additives which lower the mortar density and also helps to significantly improve the application properties. Dry mix mortars can provide better yield and thus better coverage compared to a standard site mix mortar, meaning material consumption will be less as compared to a standard site mix mortar. Typical site mix mortar has a density of approx. 2.1 – 2.2 kg / m^3 whereas for a dry mix mortar it is approx. 1.7 – 1.8 kg / m^3

Here is an example for a 50 kg bag of dry mix and 9 liter of water addition:

Using site mix

$$\frac{\text{50 kg site mix mortar + 9 liter water}}{\text{2.1 (density of mortar)}} = \text{28 liter yield}$$

28 liter yield is equal to coverage of 1.8 m^2 at 15 mm thickness

Using dry mix mortar

$$\frac{\text{50 kg dry mix mortar + 9 liter water}}{\text{1.7 (density of mortar)}} = \text{34 liter yield}$$

34 liter yield is equal to coverage of 2.2 m^2 at 15 mm thickness

It is evident from the above results that by using dry mix less material can be applied to obtain similar coverage using a site mix mortar.

Efficiency of dry mix mortars (ref:a)

As discussed in the earlier sections, dry mix mortar is known for its efficiency i.e., faster application. Here is another example on the amount of time one can save using a spray applied cement base plaster vs. a site mix plaster from the UAE market. These data are for cement base plaster supplied in bags and applied by spray machines.

Technology	Number of workers	Hours (8hrs/ shift)	Area covered
Cement spray plaster in bags	4	32	25 – 30 m^2
Site mix cement plaster	8	64	25 – 30 m^2

Table 1: Cement Spray Plaster Efficiency Calculation Example

The savings that can be made in terms of both time and manpower is tremendous and self explanatory using the data in Table 1. Note that efficiency savings can even be even higher when a silo system is used for transportation rather than bags.

Impact on Carbon Foot Print (ref:b)

The Arabian Gulf countries are major oil and natural gas producers and unfortunately fall into the top 25 countries of carbon dioxide emissions per capita. They collectively hold 40 % of the world's proven oil and 23.6 % of the world's proven gas reserves. Saudi Arabia, with 26 million people of the 39 million that live in the GCC, ranked last in the list of 57 countries responsible for more than 90 % of global energy-related CO_2 emissions – known as the Climate Change Performance Index 2009 (CCPI).

Here is another example on how dry mix mortar can contribute to the sustainability of buildings, using the calculation of embodied carbon dioxide for dry mix mortar vs. a site mix mortar. This specific case is for a dry mix mortar supplied from a factory in Dubai to Masdar city in Abu Dhabi. The comparison is made for a base plaster with cement sand ratio of 1:4 / 5 vs. a factory premixed cement base plaster.

The amount of embodied carbon dioxide per m^2 at 15 mm thickness application was calculated to be as follows:

4.21 kg embodied carbon dioxide for a site mix base plaster
< 2.5 kg embodied carbon dioxide for a dry mix

Again this is another example of the positive impact of dry mix mortars on sustainability targets.

Enhancing the durability of cement based tile adhesives (ref:c)

Adhesion properties are among the critical customer requirements for cement based tile adhesives, as they determine the durability of the whole system. Additives used in the tile adhesives formulation - such as redispersible polymer powder (eg: DOW™ Latex Powder) and cellulose ethers (eg: WALOCEL™ methyl cellulose) - are crucial to achieving higher bonding strength, thereby extending durability. Figure 1 shows the impact of dosage of DOW™ Latex Powder on adhesion properties under different conditions.

Open time is another critical customer requirement for tile adhesives that has an impact on the overall durability. Open time is greatly influenced by cellulose ether additives such as WALOCEL™ cellulose ether in the formulation. Figure 2 shows the impact of WALOCEL™ dosage on the open time properties of a cement based tile adhesive formulation.

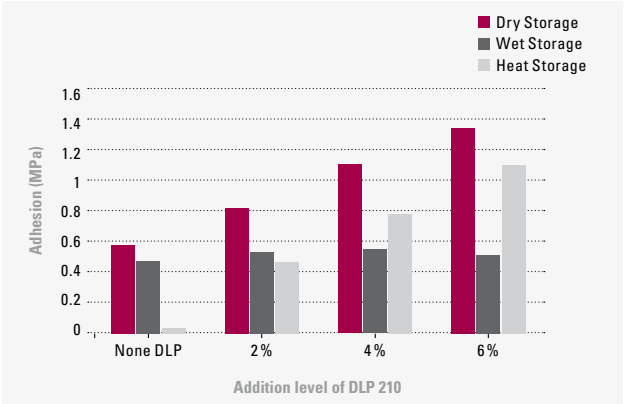

Figure 1: Impact of DOW™ Latex Powder on the Adhesion Property of Cement Based Tile Adhesive

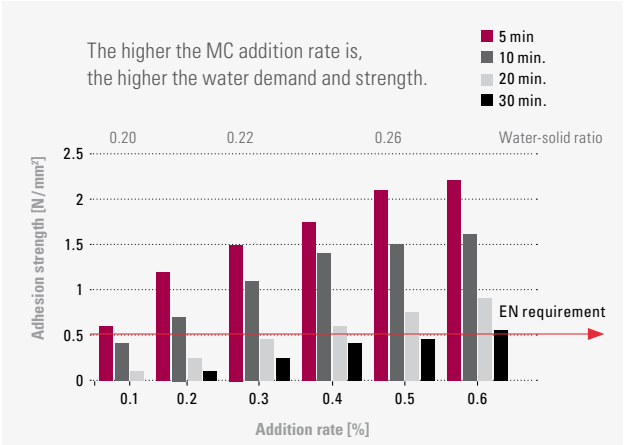

Figure 2: Impact of the Dosage of WALOCEL™ MKX 45000 PP 10 on the Open Time Property of Cement Based Tile Adhesive

Energy saving using External Thermal Insulation Composite Systems (ETICS[1])

The function of ETICS is to provide thermal insulation for buildings. It is an increasingly popular choice for building insulation in cold climate countries, but has also proved to be equally acceptable in terms of insulating against heat. Rising energy consumption in the Middle East is now a prime concern and the insulation products used on a project can have a huge impact on a building's life cycle costs. The Arabian Peninsula is characterized by extreme hot weather conditions and insulation systems such as ETICS could be an ideal solution to help support energy conservation in the region. Below are some data taken from a study carried out in the Kingdom of Saudi Arabia for a dry mix mortar based ETIC system as compared to standard houses with other materials and without insulation.

1) Sometimes referred to as EIFS, Exterior Insulation Finish Systems

HOUSE TYPE					
ANNUAL ELECTRIC ENERGY CONSUMPTION (kWh)					
	COOLING	HEATING	FAN	EQP+LTG	TOTAL
Base House	100353	16827	4542	16571	138293
Insulated House	57665	3464	2571	16571	80271
% Change of Energy	-42.5	-79.4	-43.4	0	-42

Table 2: Effect of Thermal Insulation on Energy Consumption for Base House

The base house is built using heavy weight concrete blocks and the insulated house has an ETIC system using 50 mm thick STYROFOAM™ boards and dry mix mortar based adhesives and base coats.

	Annual Total Energy Consumption, kWh	Annual Energy Cost, SR*	Annual Energy Savings, SR**
Heavyweight Concrete Block House (Base House)	138293	22360	–
Lightweight Concrete Block House	128826	20138	2222
Red Brick House	125450	19369	2991
Sand Lime Brick House	138324	22409	No savings
Gypsum Block	120013	18147	4213
Insulated House	80271	9382	12978

Table 3: Comparison of Energy Costs (in Saudi Riyals) for a Typical House Built with Different Types of Building Materials

* Electric energy rate (on monthly basis) data obtained from the Saudi Electric Company Dammam

** Energy savings as compared to that of the base house

STANDARDS FOR DRY MORTARS

Standards are often seen as overregulation but in reality standards are necessary to ensure people associated with the construction industry speak the same language and talk about products and materials in commonly understood ways. Standards are also critical to help ensure security for end users and in general the industry welcomes this. In this section, a brief introduction to the European standards for cement based tile adhesives, cement renders and ETICS will be covered.

Cement based tile adhesives (ref:c)

Cement based tile adhesive is one of the largest dry mix mortar applications and also one of the first dry mix applications to be commercialized. Polymer modified thin-bed mortars became popular in the mid 1980's due to their excellent application properties and long term durability. Critical properties required for tile adhesives are open time, workability, slip resistance and adhesion properties under different conditions.

EN 12004, EN 12002 and its sub norms are the main European norms that apply to cement based tile adhesives. The norm EN 12004 specifies the values of performance requirements for all ceramic tile adhesives [cementitious (C), dispersion (D) and reaction resin (R) adhesives]. The letters describe one out of three types of adhesive with the following designation:

– C = Cementitious based thin-bed adhesives (mortars)
– D = Dispersion adhesives (mastics)
– R = Reaction resin adhesives (epoxies and urethanes)

Each type can be divided into two classes with the number designation:

– Normal adhesive 1
– Improved adhesive 2

This classification works alongside with additional characteristics. Cementitious tile adhesives – classes according to EN 12004 & EN 12002 are:

– F = mortar with accelerated setting (which is either fast-setting or fast drying) (only for cementitious mortars)
– T = mortar with reduced slip
– E = mortar with extended open time (only for cementitious mortars and dispersion adhesives of class D2)
– S = deformable mortar (S1) or highly deformable adhesive (S2) (for cementitious adhesives only) (EN 12002)

Class	Tensile adhesion strength [N/mm²] 1)	Deformability [mm] 2)	Open time [N/mm²] after embedding time of …			Adhesion strength after 6 h [N/mm²]	Slip [mm]
			10 min	20 min	30 min		
C1	≥ 0.5	-		≥ 0.5			
C1S1	≥ 0.5	≥ 2.5		≥ 0.5			
C1E	≥ 0.5	-			≥ 0.5		
C1T	≥ 0.5	-		≥ 0.5			≤ 0.5
C1F	≥ 0.5	-	≥ 0.5			≥ 0.5	
C1ET	≥ 0.5	-			≥ 0.5		≤ 0.5
C1FT	≥ 0.5	-	≥ 0.5			≥ 0.5	≤ 0.5
C2	≥ 1.0	-		≥ 0.5			
C2S2	≥ 1.0	≥ 5.0		≥ 0.5			
C2E	≥ 1.0	-			≥ 0.5		
C2T	≥ 1.0	-		≥ 0.5			≤ 0.5
C2F	≥ 1.0	-	≥ 0.5			≥ 0.5	
C2ET	≥ 1.0	-			≥ 0.5		≤ 0.5
C2FT	≥ 1.0	-	≥ 0.5			≥ 0.5	≤ 0.5

1) Storage conditions according to EN 12004 as follows: Standard= 28 d at 23°C; Water= 7 d at 23°C + 21 d water immersion; Heat= 14 at 23°C + 14 d 70°C + 1 d 23°C; Frost= 7 d at 23°C + 21 d water immersion + 25 frost-thaw-cycles < acc. to EN 1348; four storage conditions
(Heat and frost-thaw conditioning optional; labelling as "NPD=No Performance Determined")
2) According to EN 12002

Table 4: Cementitious Tile Adhesives – Technical Requirements according to EN 12004 & EN 12002

Table 4 provides an overview of the various technical requirements necessary in order to achieve different classifications according to the EN 12004 & EN 12002 norms.

There are also different sub standards that apply to the testing and requirements of individual properties. Table 5 lists the important sub norms that apply to cement based tile adhesives.

Table 5: Cementitious Tile Adhesives – EN Sub Standards

Specification number	Type of specification
EN 1308	Determination of slip resistance
EN 1346	Determination of adhesion strength (open time)
EN 1347	Determination of wetting
EN 1348	Determination of adhesion strength
EN 12002	Determination of deformation
EN 12004	Definition of tile adhesive

CEMENT RENDERS

The most important requirements for cement renders are easy workability, low stickiness to the tool, high non sag properties and crack free setting. The primary function of plaster is that of protection against weathering or chemical or mechanical actions and therefore good adhesion to the substrates and low water absorption properties are also important requirements for cement renders. Standard tests on laboratory scale for Cement Spray Plaster include: water retention, consistency, air pore content, setting time, compressive strength and water absorption. European norm 998 provides a clear definition and classification for cement renders.

Short description	Type
GP	General Purpose Mortar
LP	Light Weight Mortar
CR	Colored Render
OC	One Coat Mortar
R	Renovation Mortar
T	Thermal Mortar

Table 6: EN 998: Definition of Mortar Used for Construction

Properties	Category	Value	Unit
Compression strenght after 28 d	CS I	0,4 - 2,5	N/mm²
	CS II	1,5 - 5,0	N/mm²
	CS III	3,5 - 7,5	N/mm²
	CS IV	> 6,0	N/mm²
Capillary water absorption	W 0	no requirements	
	W 1	c < 0,4	kg/m² min ^{0,5}
	W 2	c < 0,2	kg/m² min ^{0,5}
Thermal conductivity (just T)	T 1	< 0,1	W/mK
	T 2	< 0,2	W/mK

Table 7: EN 998: Classification of Dry Mortars Properties

While EN 998 provides definitions for various mortars and also gives the classification for mortars, EN 1015 is the standard that applies to the test methods for assessing various properties of cement renders. Table 8 provides an overview of the different tests that are critical for the characterization of cement render properties.

Specification number	Type of specification
EN 1015, part 1	Granulometric analysis – sieve analysis
EN 1015, part 3	Consistency of slump
EN 1015, part 6	Determination of bulk density
EN 1015, part 7	Air content
Draft EN 1015, part 8	Water retention

Table 8: EN 1015: Various Tests Methods for Characterization of Cement Spray Plaster and Other Cement Based Mortars

External thermal insulation composite system (ETICS)

ETICS are an application with immense potential in the Middle East region due to the rising energy needs in the region. The main critical customer requirements for ETICS mortars are the adhesive strength of the adhesive mortar and impact resistance of the base coat mortar.

The two main standards that apply to ETICS are:
- ÖNorm (Austrian Standards Institute Development)
- ETAG 004,a European standard compiled by EOTA (European Organization for Technical Approval)

The ÖNorm (Austrian Norm) 6121 defines requirements for the adhesive mortars.
The ÖNorm (Austrian Norm) 6123 defines requirements for the glass fiber mesh reinforced base coat. The requirements for the adhesive mortar according the ÖNorm are as follows:
- measurements according to ÖNorm 6121 (superseded by EN 13499)
- pulling mortar probe from EPS substrate requires minimum adhesive strength of 0.1 N/mm² after 28 days of storage at RT (and 24 hrs water immersion).

The impact resistance for base mortar is measured in a similar way for both ETAG 004 and ÖNorm. The requirement is passing 3 Joule impact without any crack formation using the pendulum impact test.

CONCLUSION

Dry mix mortars present a great opportunity for the Middle East region to raise standards for the building industry in a sustainable manner. Dry mortars also offer a potential solution for the region to meet quality and durability requirements for buildings in the region. Thanks to its high efficiency and higher performance standards, dry mortar technology also provides cost advantages vs. conventional site mix dry mortars. In addition, dry mortar based applications can offer a more sustainable solution for constructing buildings: as described in this report there are many parameters of dry mortar technology can contribute to more sustainable design.

Many dry mix mortar based applications are already practiced in the region and applications such as tile adhesives are very well established. However, one of the major challenges the region faces today is the lack of appropriate norms and standards for dry mortar technology. The role of government bodies will be critical in ensuring that the industry is strictly following standards by way of laws or regulations. The role of different players in the construction industry value chain (suppliers, manufacturers, architects, consultants, contractors etc.) will also be critical in implementing appropriate norms and standards for this region.

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