Performance of dolomitic cementitious mortars as a repairing material for normal concrete in Egypt

M. E. EL-FAKHARANY ▪ Housing and Building National Research Center, Egypt
M. EZZAT ▪ Housing and Building National Research Center, Egypt
A. GAD ▪ Geology Department, Faculty of Science, Ain-Shams University, Egypt
N. G. ABDEL GHAFOUR ▪ Housing and Building National Research Center, Egypt
A. R. BAGHDADY ▪ Geology Department, Faculty of Science, Ain-Shams University, Egypt

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Abstract

The use of dolomitic aggregate in preparation of cementitious repairing mortar really depends on their mineralogical composition and physico-mechanical properties. The physico-mechanical properties and chemistry of the selected local dolomitic aggregates were evaluated and compared with those of natural siliceous sand minerals. The studied dolomitic aggregates have a convenient chemical composition to be used as a concrete aggregate. Whereas they show relative variations in their physico-mechanical properties especially the grain size distribution, which will of course reflect the characteristics of the repairing mortar mix.

The compatibility of some cementitious repair mortars characteristics casted by dolomitic aggregates was assessed. Showed that dolomitic aggregate possess a clear effect on the properties of cementitious mortar rather than the natural siliceous sand. Also, using of this type of aggregates improves the compatibility with most commonly concrete used in Egypt by justification of the cementitious mortar mix with the suitable admixture. Assisted that most of the studied mixes show good compatibility with the casted concrete depending of appropriate composition.

Keywords: Cementitious repairing mortar; Aggregate; Physico-mechanical properties; Dimensional stability; Drying shrinkage; Compressive strength; Bond strength.
Kulcsszavak: Cementbázisú javítóhabarcs,; Adalékanyag; Fiziko-mechanikai tulajdonságok; Méretstabilitás; Száradási zsugorodás; Nyomószilárdság; Kapcsolati szilárdság.

Maged Ezzat EL-FAKHARANY
Assistant researcher in Raw Building Materials Technology and Processing Research Institute, Housing and Building National Research Center (HBNRC), XRD laboratory member since 2010, and working on Ph.D in Geology.

Mohamed Ezzat TAHA
Researcher in Raw Building Materials Technology and Processing Research Institute, Housing and Building National Research Center (HBNRC), XRD and Petrography labs member.

Ahmed GAD
Lecturer of Geology at the faculty of Science, Ain-Shams University

Nasser Gamal Abdel GHAFOUR
Professor of Geology of Raw Building Materials, Housing and Building National Research Center (HBNRC)

Ashraf Rushdi BAGHDADY
Professor of Geology at faculty of Science, Ain Shams University

1. Introduction

Continuous rapid urbanization in Egypt was followed by the appearance of concrete deteriorating problems. Repairs would be successful in the long-term if original caused damages are avoided by applying appropriate repairing materials to resist the future deterioration, [1]. Having good experience of repairing process with higher initial quality of the used repairing material, results in postponement of repair and, in the end, a reduction of the costs for maintenance and repeat the repair. One of the most challenging and interesting tasks in the field of concrete repairing is to choose and evaluate local repairing materials used. Without knowledge about building materials used it would not be possible to build safe, efficient and long-lasting buildings. The performance of a repaired concrete structure, and thus its service life, depends mainly on the quality of the repairing material composite [2]. Today cementitious materials especially of Portland cement represent the majority of our binding materials. Cementitious materials are defined as compounds that are mixed easily and react with water results in hydration products of calcium silicates (C-S-H), which bind the constituents together. These hydrated phases contribute to cement matrices densification and thus, to improve the mechanical properties and durability [3]. Cementitious repairing mortars mixed with local dolomitic aggregate can offer a number of advantages such as availability, cheapness, easy production with large volume and its compatibility with the older local common concrete. Repairing materials only with cementitious binders can provide acceptable protection to existing concrete structures, [4]. Addition of different percentages of mineral admixtures may also enhance the performance of a cementitious repairing mortar thus improve the compatibility with concrete substrate.

Good bond between the repair and the existing concrete substrate is a primary requirement for a successful repair [5]. This generally requires that the repairing material have high strength, be well bonded and compatible with the substrate. The final requirement is the repairing material should have properties that enable it to be dimensionally stable relative to the substrate [6-8]. This frequently requires that the repair materials have a low drying shrinkage and that these materials have a coefficient of thermal expansion that is similar to the substrate. Cementitious materials are locally available and it can mix with any natural aggregate and additives. The selection of a suitable additive to make a successful cementitious repair mortar depends mostly on using a suitable elected aggregate. In this case the set properties are strongly influenced by the cementitious composites especially the characteristics of aggregate used as discussed by [9].

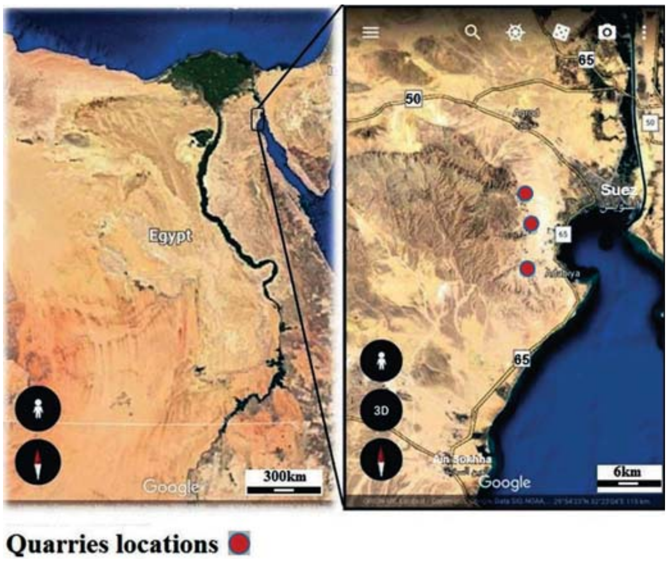

Fig. 1 Satellite image shows the locations of quarrying and samples, Ataqa area, Suez City, Egypt
1. ábra A kőfejtés és mintavétel helyei műholdképen, Ataqa terület, Szuez, Egyiptom

Oxide content (wt,%)	OPC	EPP	CS
SiO_2	20.61	74.69	50.6
Al_2O_3	4.72	9.91	25
Fe_2O_3	3.31	0.59	9.7
CaO	62.65	2.19	4
MgO	2.12	0.01	2.5
SO_3	2.8	0.04	0.009
Loss of Ignition (LOI)	3.11	1.48	1.05
Na_2O	0.39	5.65	1.98
K_2O	0.23	4.66	2.9
TiO_2		0.14	1
P_2O_5		0.03	0.001
Total	99.94	99.39	98.74
Ins.Res	2.71		
Na_2OEq	0.24		
C_3A	5.98		
C_3S	51		
C_2S	22.05		

Table 1 Chemical composition of the used OPC, EPP and CS admixtures
1. táblázat Az alkalmazott OPC, EPP és CS adalékok kémiai összetétele

2. Materials and methods

2.1 Raw materials used

Aggregate representative samples were collected from different quarries stockpiles at Ataqa area- Egypt and coded Dol.1, Dol.2 and Dol.3, (*Fig.1*). More than 150kg for each aggregate type was collected to measure its performance in mortar mixes for repairing concrete. Three aggregate samples were elected and coded. A natural sand sample is collected from Jabal El Sheeb quarry, 6th October City, Egypt.

The type of cement used was the Egyptian Ordinary Portland Cement (OPC-CEMI with Rank 42.5) produced by Tourah Cement Company. Its chemical analysis was performed and found to agree with the standard specifications, (*Table.1*). The mineral admixtures used were expanded perlite powder (EPP) made in Egypt by the Egyptian Company for Expanded Perlite (E.C.P.V.), Batch year 2016 and an import coal slag (CS) with cement replacement percentages (5, 10, and 15%).

2.2. Aggregate evaluation

There is recommendation to add high quality aggregate to repairing mortars according to [6].The chemical and mineralogical investigation of carbonate aggregates were done using Axios (PW4400) WD-XRF Sequential Spectrometer (Panalytical, Netherland) and X-ray diffractometer, (model X'Pert Pro, Phillips MPD – Manufactured by PANalytical B.V Co., Netherlands - ISO 9001/14001 KEMA - 0.75160) provided with (Cu) anode at 40 kv&30 mA with a scanning speed of 2° / minute. The elected aggregates will be used in a repair mortar mix should have a physical and mechanical characteristics meet the ASTM C33 specification [10].

Mortar Mix	Mix proportions (kg/m³)						
	Cement	Aggregate		Water	SP	Additive	
M.Dol.1	571	1630		224	4.6		
M.Dol.2	571	1630		224	4.6		
M.Dol.3	571	1630		224	4.6		
M.Sand	568	1622		223	4.5		
		(Dol.1)	(Dol.2)			EPP	CS
M.Dol.C(MD.C)	571	981	644	224	4.6		
M.D.C. 5%EPP	542	981	644	224	4.6	28.6	
M.D.C.10%EPP	514	981	644	224	4.6	57.1	
M.D.C.15%EPP	485	981	644	224	4.6	85.6	
M.D.C.5%CS	542	981	644	224	4.6		28.6
M.D.C.10%CS	514	981	644	224	4.6		57.1
M.D.C.15%CS	485	981	644	224	4.6		85.6

Table 2 Mix proportion of the studied cementitious mortars (kg/m³)
2. táblázat A vizsgálat cementbázisú habarcsok keverési összetétele (kg/m³)

2.3. Mortars properties tests

The mixed repairing mortar was defined as all concrete constituents with a smaller aggregate particle size pass 9.5mm sieve, i.e., aggregate <9.5mm, cement, water and super plasticizer (SP), (*Table2*). For concrete substrate the proportion by mass 1:1.9:3.6 (cement: sand: carbonate aggregate) trail mix was used with W/ C ratio = 0.5, to gain normal concrete with strength reaches approximately 41 MPa. For the substrate and repairing mortars compressive strength test on 3 cubic concrete samples for each mix were performed at ages of 1, 3, 7, 28 and 90 days. In each case, this test was carried out on specimens following the procedure described by Egyptian Code for the design of concrete structures [11]. Mortar cubes water absorption was performed according to the test procedure ASTM C642 [12]. The procedure for determining the coefficient of thermal expansion of repair mortars is used where mortar prisms are exposed to temperatures ranging from 5 to 60 °C [13]. The drying shrinkage test was carried out according to ASTM C157/C157M [14], also slant shear test according to ASTM C882 [15].

3. Results and discussion

3.1. Aggregates

3.1.1. Chemical and mineralogical composition

Chemistry of carbonate aggregate samples shows that CaO is the highest recorded oxide followed by MgO (*Table.3*). On the other hand, the sand aggregates show high content of SiO_2. These facts are related to the mineralogical composition of the studied aggregates. The carbonate aggregates are mainly composed of dolomite and calcite; meanwhile the sand aggregates are dominated by quartz (*Fig.2*). The carbonate aggregates can be classified according to their MgO % into dolomite (Dol.1&Dol.2) and calcitic dolomite (Dol.3), [16]. Dol.3 sample show relatively higher contents of SiO_2, Al_2O_3, Fe_2O_3 and loss in ignition than those of other carbonate aggregates, that may be related to the presence of impurities. All samples show low Na_2O and K_2O contents however the sand recorded relatively higher alkali contents than carbonate aggregates. SO_3% is relatively higher in carbonate aggregates than those of sand, however this percentage still in acceptable limit (0.02-0.12%). On the other hand, carbonate aggregates especially Dol.3 sample have unacceptable chloride limit according to the Egyptian specification [11].

Oxide content (wt,%)	Dol.1	Dol.2	Dol.3	Sand
SiO_2	1.09	0.48	1.32	97.16
CaO	35.6	38.42	33.7	1.54
MgO	19.3	20.61	18.7	0.11
Al_2O_3	0.23	0.12	0.55	0.05
TiO_2	0.07	0.07	0.06	
Fe_2O_3	0.19	0.17	0.21	0.05
Na_2O	0.11	0.04	0.13	0.19
K_2O	0.04	0,02	0.06	0.11
P_2O_5	0.11	0.05	0.05	
SO_3	0.1	0.12	0.02	0.01
Loss of Ignition (LOI)	42.9	39.7	45.2	0.39
Total	99.74	99.78	100	99.97
Chloride ion(Cl)	0.06	0.09	0.1	0.09

Table 3 Chemical composition of the studied aggregates
3. táblázat A vizsgált adalékanyagok kémiai összetétele

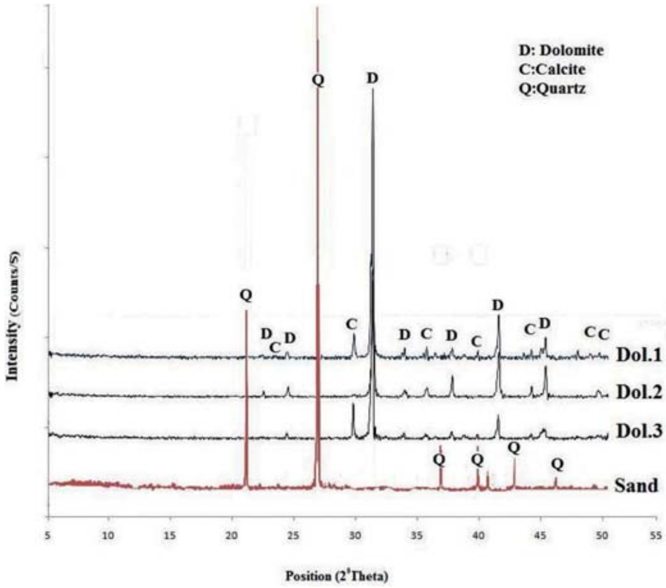

Fig. 2. XRD patterns of the different studied aggregates
2. ábra A vizsgált adalékanyagok XRD elemzése

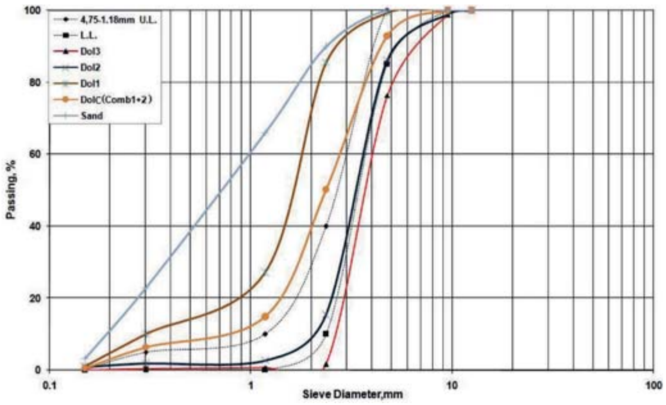

Fig. 3. Grain size distribution curve of the studied aggregates
3. ábra A vizsgált adalékanyagok szemmegoszlás görbéje

3.1.2 Physico-mechanical properties

3.1.2.1 Grading

Using of well and densely graded aggregates is highly recommended for repairing mortar, to reduce the required cement paste and minimize the risk of debonding, via shrinkage reduction [17]. Also, the grading affects the workability and finishing quality of mortar and concrete [18]. The studied dolomitic aggregates show variations in grain size distribution (*Fig.3*). The grading curves are lined near the zone of size number (9) limit according to ASTM D448 [19]. Dolomitic aggregates are falling within the coarse sand size especially sample Dol.1 when compared with the natural sand aggregate. Sample Dol.3 exceeds the upper limits of the size number (9) which disagrees with the concept of repair [20], while Dol.1 sample deviates toward the sand fractions and pass its lower limit. Void contents increase with decreasing in aggregate size to about (40%-50%) for fine aggregates [21]. This may lead to higher amount of cement paste and more shrinkage. Dol.2 sample have a good grading distribution curve and in the case of combined sample (Dol.C), the distribution curve is slightly shifted to sand size. This combination may be helpful to use wide size range and mostly of smaller sizes as possible. Satoh et al., [22] stated that the suitable sizes of aggregates should line with treated roughness of the substrate surface for best repairing. Such these dolomitic aggregates grading could positively affect the aggregate interlock and may lead to good bonding.

3.1.2.2 Bulk density

The bulk density of the studied dolomitic aggregate samples ranges from 1.30 to 1.36 g/cm^3 with an average value of 1.32 g/cm^3. While natural sand sample shows the highest recorded bulk density value (1.47 g/cm^3) and considered the densest aggregate (*Fig. 4*). That can be attributed to the smallest sand fractions which help in fissuring and decrease voids space. Recorded bulk density values are considered reasonable to good mortar with normal weight which requires less cement. It should be known that, normal aggregate weight will have good workability and has been considered resistant to length change due to drying [23]. Variation of bulk densities values for dolomitic aggregates compared with sand aggregate may relate to their angularity and abundance of coarser size fractions. It is well known that, angularity shape of aggregate is a very important factor that causes changes in the relative density values as indicated by [24, 25]. Low bulk density values can increase voids contents between aggregate particles [21], leading to higher cement paste and so higher shrinkage. So, samples with normal weight should be used and total volume of voids can be reduced by using a combination of aggregate sizes.

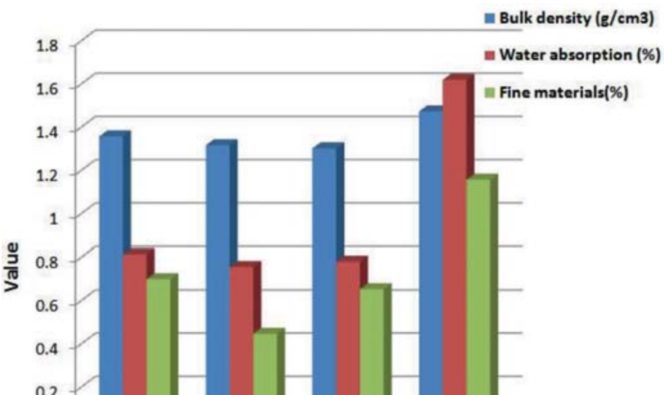

Fig. 4. Correlation between bulk density, water absorption and fine materials values of the studied aggregates
4. ábra A vizsgálat adalékanyagok halmazsűrűsége, vízfelvétele és finomrész aránya

3.1.2.3 Fine materials and water absorption

The percentages of fine materials (*Fig.4*) revealed that all studied aggregate samples don't exceed the value of 1%, except sand sample. These values agree with the ASTM C142 limits [26], that give chance to use such aggregates for a repairing mortar. There is a direct relation between the water absorption and presence of fine materials. All recorded values lie within the standard limits [27, 28]. Dolomitic aggregates seem to be relatively lower in water absorption than sand. Their values are relatively close to combined substrate aggregates values, which may enhance the compatibility. In addition to presence of fines the high water absorption may related to the iron oxide as deleterious substances which may contribute to more shrinkage. The Drying shrinkage test in BS 812 -120 [29] is limited to aggregate with water absorption less than 3.5%. Length change seems to be caused by change in surface energy of most aggregate due to absorption [23]. Generally, it shouldn't use aggregate with high water absorption which will not be more safely in repairing of concrete. Since the mechanical adherence with high water absorption may be prevented from occurring as discussed by [30].

3.2 Mortar

3.2.1Physico-mechanical properties

Suitable repair mortar mix allows cementitious repair materials to easily penetrate and hydrate into substrate cavities. The slump values of fresh mortar mixes with dolomitic aggregates ranges between 4.9 and 6.8 cm. While mortar made with natural sand show moderate value equal 5.6 cm. Therefore, all studied mixes are considered of medium workability. ACI 224.1R [31] recommended using of the lowest possible slump to reduce shrinkage and avoid occurrence of cracks, so a combination of dolomitic samples is more acceptable to use.

Dry density of studied mortar cubes already matches with bulk density of aggregates and compatible with substrate (*Fig. 5*). Dolomitic mortars show similarity in dry density which range from 2.39 to 2.41 g/cm^3. Mortar with natural sand show the dense value (2.42 g/cm^3), that related to the good packing shown by sand particles. The main causes of little difference in weight between mortars may relate to grading, shape and composition of aggregate, [21]. Spherical particles like natural sand lead to good backing and so better workability, [32]. The crushed dolomitic aggregates that yield grains with angular corners cannot be workable enough like sand [18]. They still have slightly compatible nature with the substrate density. But when additives applied, EPP mortar cubes showed decrease in dry density with increasing cement replacement unlike CS mortars. That simply relate to the relatively high specific gravity of such additive. Therefore high dosages affect on mass unit compatibility with the normal concrete substrate.

Good adherence of mortar is recommended by using amix with lower water absorption than the substrate [30]. It can be observed that water absorption of all studied mixes is lower than substrate value (*Fig. 5*). Mortar made with dolomitic aggregates shows approximately similar values with an average equal 0.9%. While the comparable sandy mortar shows the highest water absorption value (1.5%) among all studied mixes. This may be due to the higher percent of fine materials in that aggregate which influence the concrete absorption, [33]. To some extent, there is relation between the densities of the studied mortars and their water absorption values. It can be noticed that water absorption of mortars mixed with EPP increase with decreasing density and increasing cement replacement. This fact may be related to water uptake due to the high surface area gained by these additives. EPP could be used in small quantities as a cement replacement due to its high water absorption capacity [34]. However, in case of CS there is a slight decrease with increase dosages and density that means CS did not have the ability to excess water uptake. This reflects that aggregate type and mortar composition may influence water absorption of the produced repairing mortars.

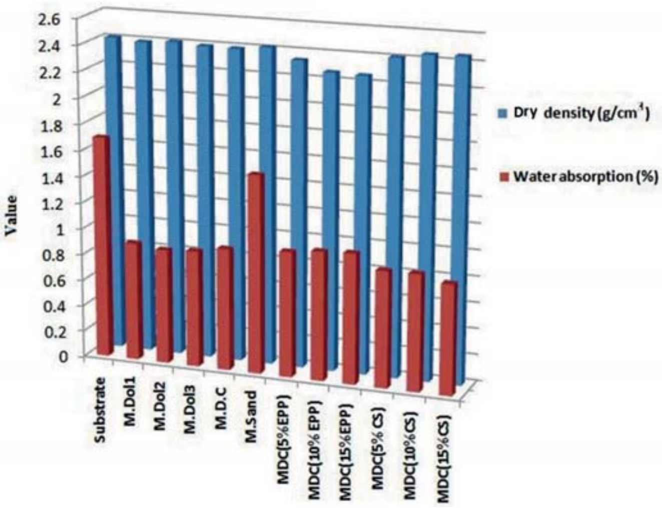

Fig. 5. *Correlation between the values of dry density and water absorption of the studied cube mixes*
5. ábra *A kocka minták sűrűsége és vízfelvétele közötti korreláció*

3.2.2 Dimensional stability

3.2.2.1 Length change (Dry shrinkage)

Cementitious mortar mix with an excess of binder may lead to high shrinkage and mortar cracking. Therefore, excessive shrinkage of a cementitious repair mortar can be a main cause of the repair failure. There is a suggestion to use very low shrinkage cementitious mortars for concrete repair by [35]. All studied mortar mixes show drying shrinkage ranging from 0.0053% to 0.01% after 28days (*Fig.6*), (*Table 4*); therefore, they are considered very low shrinkage according to [36]. Also they should be desirable since the point of view is "shrinkage of a cementitious mortar should be less than that of concrete" as mentioned by [7]. Dolomitic mortars showed relatively lower shrinkage values range between 0.0053 and 0.0086% after 28 days, and 0.0072 and 0.0092% after 2 months. While the comparable natural sandy mortar showed the highest shrinkage value (0.01%) after 28days between the studied samples, then its value seems to be constant for 2 months. However, it is considered acceptable since the repair mortar to concrete substrate relation is (R<C).

The relatively high shrinkage of natural sand mortar relate to its relatively high absorption and more fines in that aggregate. Grassl et al., [37] reported that the concretes shrinkage depends primarily on the used aggregate properties. However, some mineral admixtures are capable to reduce shrinkage as documented by [38]. Mortars with EPP and CS after 28days show drying shrinkage increasing reached to 0.0065 and 0.0072%, respectively with the replacement level 15%, although they are still compatible with the substrate.

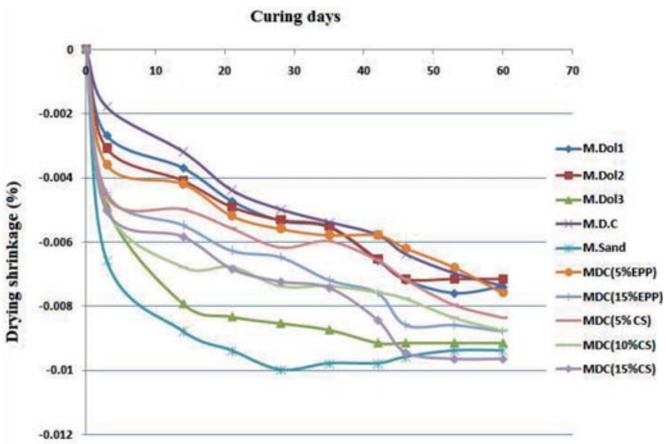

Fig. 6. *The change of drying shrinkage between the studied mortar mixes.*
6. ábra *A száradási zsugorodás változása időben az egyes habarcskeverékek esetében*

Mortar Sample	Shrinkage, 28days (%)	Shrinkage Relation	Thermal Expansion	Thermal Relation
M.Dol.1	0.0054	Classified as Very low - R < C (where the substrate shrinkage equals = 0.01444%)	4.87E-06	R < C (where thermal expansion coefficient equals = 6.77162E-06)
M.Dol.2	0.0053		5.18E-06	
M.Dol .3	0.0086		5.44E-06	
M.Sand	0.01		6.56E-06	
M.D.C	0.0054		5.44E-06	
M.D.C. 5%EPP	0.0056		5.32E-06	
M.D.C.10%EPP	0.0063		5.28E-06	
M.D.C.15%EPP	0.0065		5.18E-06	
M.D.C.5%CS	0.0062		4.85E-06	
M.D.C.10%CS	0.0074		6.48E-06	
M.D.C.15%CS	0.0072		6.76E-06	

Table 4 *Shrinkage, thermal expansion coefficients values of the studied mixes and their relations with the substrate*
4. táblázat *A vizsgálat keverékek zsugorodása, termikus hőtágulási együtthatója és a ezek kapcsolata a bányászott anyag ezen tulajdonságaival*

3.2.2.2 Thermal expansion

Thermal stability of cementitious mortar and their dimensional compatibility with existing substrate may impact the repair success. Types of aggregates have main influence on this property, [39]. Dolomitic mortars represent the relatively lowest coefficients of thermal expansion (4.87E-06, 5.18E-06, and 5.44E-06) if compared with sand mortar value (6.56E-06), (*Table 4*). Mortar sample MD.C (with combined aggregates Dol.1&Dol.2) show good thermal stability and compatibility with the substrate without any additives. EPP mortars show gradual decrease of thermal expansion coefficients from 5.45E-06 to 5.18E-06 value. This may be referred to the good thermal insulation properties of EPP. That gives EPP mortars high chance to be used as a repairing material in spite of its values are relatively lower than the studied concrete substrate. Unlike CS, mortars show increase in the thermal expansion values. The chemical composition with high alumina and iron oxides of CS may contribute to their high thermal expansion. Therefore, dolomitic mortars with high CS dosages and sand mortar may be considered less thermally stable; however they have values close to that of the studied substrate. Such mixes should be avoided especially in repair dolomitic substrate because they may lead to poor bonding as recommended by [40].

3.2.3 Strength

3.2.3.1 Compressive strength

There is a variation in strength between all repair mortar samples *(Fig. 7)*. This may relate to the difference in mineralogical composition and shape of the applied aggregate [25]. The strength ranges are 4.9-6.7, 9.4-18.7 and 24-30 MPa in the early curing ages 1, 3 and 7 days, respectively. Whereas the substrate strength value still considered the highest. The higher substrate strength value in early ages than studied repair mortars may be related to coarse aggregate size and high aggregate/cement ratio. Furthermore, mortars strengths begin to exceed the substrate strength where strengths increase to the range 34-54 and 35-56 MPa during the later curing ages 28 and 90days, respectively. The high rate of strength development at late ages can be explained by the good aggregate compaction that increases mix cohesion by increase in hydration time. Also most of these values can be compatible with substrate strength purposes and classified according to EN 1504-3 [41] into R4 and R3, (*Table.5*). It can be noticed that the highest strength values between dolomitic mortars (without mineral additives) are shown by MD.C mortar sample through all curing intervals 1, 3, 7, 28 and 90 days. The aggregates used in the mix of these samples be sounded, have good grading and show relative high mortar dimensional stability with good physico-mechanical properties. Unlike, MDol.3 sample mortar is incompatible with the substrate and displays lower strength value than the other dolomitic samples. This may be related to poor grading, abundance of large particles and poor quality of aggregate. Dolomitic mortars strength did not exceed sand mortar strength. This may be related to the high specific surface area of the fine sand aggregate which lead to high bond strength between the aggregate and cement paste and increase the compressive strength [42]. Therefore, dolomitic aggregates with high quality seem to be more suitable for repairing mortar mix.

The cement consumption and the compressive strength can be adjusted by add appropriate amount of mineral admixtures. EPP mortars show slight increase of compressive strength in the early ages (1, 3, 7days) with cement replacement up to 10%, and still lower than the control. At 28 days, they show the same behavior, while in later age (90 days), strength increase than the control mix up to 10% replacement. The strength decreased with 15% replacement although all EPP mortars are compatible with the substrate (*Table 5*). The cement replacement by 10% EPP leads to the highest compressive strength values for all samples after 90 days (*Fig.7*). It is shown that in case of EPP dense mortar form due to pozzolanic effect, as [43] indicated that perlite powder has a significant pozzolanic effect and is a good active mineral admixture for mortar. Unlike, mortars mixed with CS powder have relatively moderate strengths and are classified as (R3). These mortars show slight increase of strength up to 10% cement replacement at the early ages and strength decrease with the high replacement (15%). CS mortars show relatively higher strengths values than EPP mortars only during the first day. That means CS plays a major role as filler giving early dense mortar performance. The compressive strength of mortars with different SC dosages at 28 days show the highest value (43 MPa) with 5% replacement. Then the strength decreases gradually to (34 MPa) with 15%replacement. Therefore, coal slag is noticed to be reducing the compressive strength with increasing replacement percents and considered as undesirable for repair mixes. However, CS mortars are still compatible with the substrate, (*Table 5*). In general, the various behavior of repairing mortar compressive strength is not evident alone for good repairing material without bonding strength.

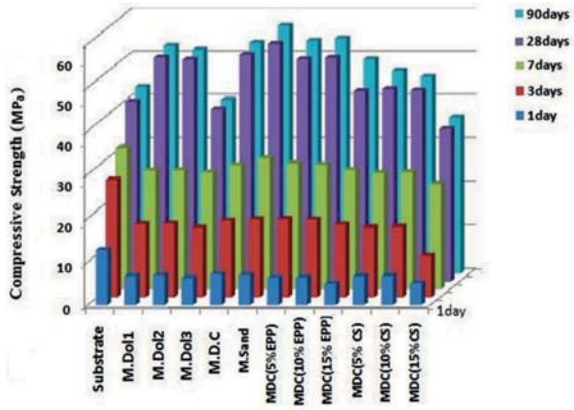

Fig. 7 Compressive strengths of all the studied repair cementitious mortars at different curing ages
7. Ábra A vizsgált cementalapú javítóhabarcsok nyomószilárdsága különböző szilárdulási korokban

Mortar Sample	Strength Classification according to EN 1504-3	Strength Relation	Bond strength Slant shear test 28d (MPa)	Bond failure
M.Dol.1	(R4)	R > C	26	Interface
M.Dol.2	(R4)	R > C	25	Interface
M.Dol.3	(R3)	R < C	20	Interface
M.D.C	(R4)	R > C	28	Interface
M. Sand	(R4)	R > C	33	Interface- with remains parts of C
M.D.C.5%EPP	(R4)	R > C	35	Interface- with remains parts of C
M.D.C.10%EPP	(R4)	R > C	26	Interface
M.D.C.15%EPP	(R3)	R > C	24	Interface
M.D.C.5%CS	(R3)	R > C	26	Interface
M.D.C.10%CS	(R3)	R > C	24	Interface
M.D.C.15%CS	(R3)	R < C	22	Interface

Table 5 Compressive strength classification, bond strength and bond failure of the studied mixes and their relations with the substrate
5. táblázat Nyomószilárdsági osztály, kötési szilárdság és kapcsolati tönkrementel típusa a vizsgálat keverékeken és ezek kapcsolata a bányászott anyag tulajdonságaival

3.2.3.2 Bond strength (slant shear test)

It can be noticed that there is a correlation between bond strength and compressive strength, (*Fig 8*). The bond strengths of studied cementitious mortars range from 20 to 33 MPa, (*Table 5*). Most of the failure mode in the slant shear test was through the interface. This indicates that the bond strength between the cementitious repair mortar and substrate is weaker than the strength of the continuous substrate and the repair mortar themselves. Momayez et al., [44] predict low adhesion for cementitious repair materials and estimate slant shear values about 80% of the continuous sample. Therefore, additive should be applied to increase the cementitious bond.

On the other hand, natural sand mortar shows the highest bond strength value in all studied mortars. This may be related to the size and grading of its particles, which in turn cause good compacting and interlocking at the rough substrate surface. Also, the investigated dolomitic mortars show variations in bond strength. Since adherence occurs by penetration of the mortar's fine elements into the substrate's pores and forming a system of mechanical anchorage [30]. Mortars with good quality and more properly fine fractions as MDol.1 and MDol.2 show relatively higher bond than the coarser MDol.3. This means that the quality of the bond largely depends on the repair mortar characteristics.

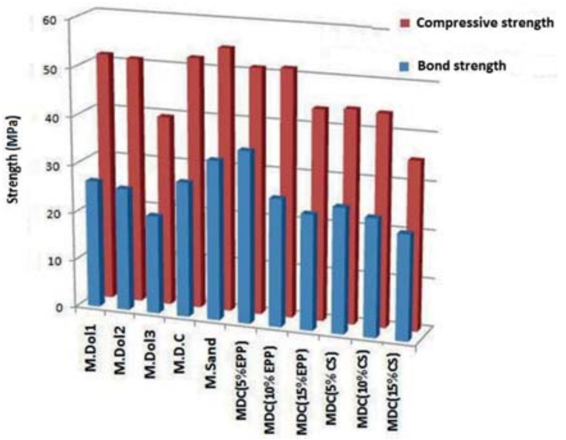

Fig. 8. The bond strength correlation between all studied cementitious mortars with different additives
8. ábra A kötési szilárdság korrelációja az összes vizsgálat cementalapú, különböző adalékanyagot tartalmazó habarcson

The selection of the repair mortars is based mainly on their bonding strength which may influence by mineral admixtures. Mortars mixed by EPP show bond strength decreasing from 35 (5%EPP) to 23 MPa (15% EPP). It is recommended that EPP could be used in small quantities as a cement replacement to prevent shrinkage and so debonding, due to its high water absorption capacity [34]. In spite of EPP mortars show relative decreasing in bond strength with replacement, however 5%EPP represents the highest bond strength value of all the studied cementitious mortars (*Fig.8*). The replacement level of all presented interface failure associated with partial damage and attached to traces of substrate (*Fig.9.a*). Good bonding of such mix may be related to the EPP pozzolanic activity, as filling voids of Interface Transition Zone (ITZ) which lead to cohesion of cement to other particles, resulting in enhancement of bonding to substrate.

Mortars mixed with CS show relatively high reduction in slant shear strength when compared with others. Replacement with 15% CS shows the lowest value (22 MPa) between all studied samples. The failure occurred only at the interface where complete separation of substrate and repair occurred, (*Fig 9.b*). The lack of pozzolanic activity in CS may be the main reason of reduction in its bond strength. Also, relatively high shrinkage observed by CS mortars may reduce bonding efficiency by initial tensile strain induced in the repair [45].

Fig. 9. a) 5% EPP mortar sample shows interface failure with partial damage and attached traces of substrate (right), b) interface failure with complete separation
9. ábra a) 5%-os EPP habarcs minta felületi tönkrementele az alapanyag részleges tönkremenetele mellett b) felületi tönkrementel teljes elválással

4. Conclusion

Well graded and dense dolomitic aggregates will positively affect interlocking and bonding by fissuring and decreasing void spaces. Avoid aggregate with high water absorption due to abundant fines, and iron oxides will be more safe in concrete repair.

Properties variation of cementitious repair mortar is due to variation in the used aggregates composition and characteristics. The studied dolomitic mortars show more dimensional stability than the comparable natural sandy mortar. This fact enhances the compatibility between dolomitic repair mortar and the normal concrete substrate.

The different behavior of repairing mortar compressive strength is not evident alone for good repairing material without bonding strength. There is a correlation between bond strength and compressive strength, most of the failure mode in the slant shear test was through the interface. Therefore, additive should be applied to increase the cementitious bond. EPP added to dolomitic mortars is preferable than CS powder for good adherence. In general, the more compressive strength of dolomitic mortar contributes to increase the adhesion strength.

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