Effect of combined use of crushed sand and Algerian desert dune sand on fresh properties and strength of self-compacting concrete

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Abstract

The main objective of this research work is to examine the influence of combined use of various types of sand on the fresh and hardened properties of SCC. The types of sand used are crushed sand (CS), river sand (RS) and dune sand (DS). In addition, binary or ternary system mixture of these sands were also used. SCC mixes were made with constant content of cement and marble powder waste. In this investigation, the flow ability was evaluated by slump flow, L-Box, J-ring V-funnel tests for SCC. The resistance to segregation was measured by GTM sieve stability test. Compressive strength was also determined at age of 28 days. The experimental results indicate that, there is an improvement in the fresh and strength properties of SCC when using binary mixtures of CS and RS. However, there is a decrease in workability and strength using binary system of CS+DS and RS+DS especially for higher DS content up to 50%. This effect was also observed with SCC containing ternary system (CS+RS+DS). Based on the results obtained of this investigation, CS and DS may provide a readily available alternative material to ordinary fine aggregates in concrete applications with competitive cost.

Keywords: crushed sand, river sand, dune sand, binary system, ternary system, SCC, fresh properties, strength

Kulcsszavak: zúzott homok, folyami homok, dűne homok, kétkomponensű rendszer, háromkomponensű rendszer, öntömörödő beton, frissbeton, szilárdság

1. Introduction

Self-compacting concrete (SCC) is a new generation of concrete that fits well with the current state of development of the structures facing a labor less qualified. This range of concrete is characterized by a high workability and a high deformability, while being stable and ensures durable structures. For achieving these contradictory properties, the formulation of SCC needs the use of high Portland cement content and superplasticizer (SP). However, using high volume of Portland cement causes many problems such as: increase in the consumption of cement; environmental impacts due to CO₂ emissions; consumption of energy and natural resources; high production cost since the cement is the most expensive element in the concrete; risk of cracking associate to the high heat of cement hydration. The SCC can be implemented without vibration, through confined areas only under the effect of gravity, while developing good compactness without requiring skilled labor during the consolidation. These properties contribute to a sustainable concrete quality. Depending on the density and complexity of the reinforcement of structural elements, the need for vibration can decrease significantly and even be eliminated, which is a labor-intensive economy [1, 2]. SCC is characterized, in general, by a formulation containing various chemical and mineral additives in precise proportions to meet the requirements of the specifications for workability and stability. The incorporation of supplementary cementitious materials improves the rheological, physical, mechanical and durability properties of SCC [3, 4]. For example, the limestone fillers are generally used to increase

the amount of powder in the composition of SCC [5]. Recycling waste powders of marble and granite in the production of SCC was proved to be useful because the marble powder acts as filler, and granite powder acts as pozzolanic material despite its small pozzolanic activity [6].

The demand for natural sand is quite high in developing countries owing to rapid infrastructural growth which results supply scarcity. Therefore, construction industries of developing countries are in stress to identify alternative materials to replace the demand for natural sand. On the other hand, the advantages of utilization of by-products or aggregates obtained as waste materials are pronounced in the aspects of reduction in environmental load and waste management cost, reduction of production cost as well as enhancing the quality of concrete. Quarry dust has been used for different activities in the construction industry such as road construction and manufacture of building materials. Crushed rock aggregates are more suitable for production of high strength concrete compared to natural gravel and sand. High percentage of dust in the aggregate increases the fineness and the total surface area of aggregate particles. In the production of crushed sand, there is a significant proportion of fines in the sand; this proportion of fines is approximately 10-15% of the total weight of crushed sand. The use of sands rich in fines may be regarded as an alternative source of fillers. These sands enhance the cost of SCC by reduction of the high demand for fillers on the one hand. On the other hand obtaining a SCC with good physical and mechanical properties such as permeability, absorption and strength [7-18].

Attempts have been made to investigate some property of quarry dust and the suitability of those properties to enable quarry dust to be used as partial replacement material for sand in concrete [19, 20]. The use of quarry dust in concrete is desirable because of its benefits such as useful disposal of by products, reduction of river sand consumption as well as increasing the strength parameters and increasing the workability of concrete [21, 22]. The overall workability value of quarry dust concrete in terms of slump as well as compaction factor was less in comparison to conventional concrete. The workability of the concrete mixes decreased with an increase in percentage of stone dust. It indicates that water requirement is higher in such concrete to maintain the desired workability [23-31]. *Celik et al.* [19] studied the effects of various proportions of crushed dust content on properties of fresh concrete and hardened concrete. Test results indicate that slump of concrete decreased as the percentage of dust content increased, and air content of fresh concrete decreased as the percentage of dust content increased. *Saeed and Shahid* [28] have found that workability of various mix ratios decreased from 11% to 67%, whereas compressive strength increased from 7% to 33% with increasing proportion of manufactured sand. *Akrout et al.* [29] investigated an experimental study on the effect of crushed limestone sand proportioning to the workability and the compressive strength of concrete. The performance of the crushed limestone sand concretes was compared with those of siliceous sand concretes. It was observed that, the properties of crushed limestone sand concretes, although lower than those of siliceous sand concretes, remain completely comparable.

Shi-Cong and Chi-Sun [32] showed that the workability of crushed fine stone CFS concrete mixes was decreased with an increase in CFS content probably due to the angular shape of the CFS when compared to river sand. Also, *Donza et al.* [33] found that when crushed sand was incorporated in concrete, the increase of water demand due to the shape and texture of the crushed sand can be mitigated by using a water reducing admixture [34]. *Rao et al.* [35] reported an increasing compressive strength by use of rock flour as fine aggregate instead of river sand. The idea of using quarry sand as an alternative aggregate was developed because granite, which is the parent material, is hard and dense and therefore can serve as an excellent aggregate material. Its use as a fine aggregate in concrete is expected to improve certain properties, such as the compressive strength, durability, strength development, workability and economy. The importance of the compressive strength in concrete is such that for structural design purposes, the compressive strength is the criterion for quality.

Menadi et al. [11] showed the influence of fines in crushed sand on the physical and mechanical properties of concrete. Four different cement types were used while maintaining a constant water/cement ratio, and examined the influence of limestone fines in crushed sand on concrete strength. The test results showed that up to 15% of fines content in crushed sand could be used without adversely affecting concrete strength. It was tried experimentally to explore the use of crusher dust, stone chips and fly ash in self-compacting concrete. Test results indicated that for SCC, sufficiently low water to powder ratio can be attained even with the use of crusher dust, leading to high compressive strength [36].

Shanmugapriya and Uma [37] concluded from experimental researchers that compressive and flexural strength of concrete can be improved by partial replacement of cement by silica fume and manufactured sand for natural fine aggregates. They suggested that optimum replacement of natural sand by manufactured sand is 50%. *Raman et al.* [38] studied the effect of quarry dust and found that the partial replacement of river sand with quarry dust without resulted in a reduction in the compressive strength of concrete. *Reddy and Reddy* [39] reported an increasing compressive strength by use of rock flour as fine aggregate instead of river sand. *Ilangovana et al.* [30] reported strength of quarry rock dust concrete was comparably more than that of similar mix of conventional concrete. *Hameed and Sekar* [31] studied effect of crushed stone dust as fine sand and found the flexural strength increases than the concrete with natural sand but the values decreases as percentage of crusher dust increases.

Ilangovana et al. [30] found that the natural river sand, if replaced by hundred percent quarry rock dust from quarries, may sometimes give equal or better than the reference concrete made with Natural Sand, in terms of compressive and flexural strength studies. Also, they concluded that the replacement of fine aggregate with 50% marble powder and 50% quarry rock dust gives an excellent result in tensile strength. *Poon et al.* [34] reported that the hardened properties of concrete mixes with partial proportions of manufactured and natural sand achieved a higher compressive strength at all test ages for normal strength, intermediate strength and high strength concrete.

In many desert regions, there is an abundance of fine sand dunes, particularly in Sahara desert of Algeria, which covers more than 60% of its area. The idea of promoting its value in the manufacturing of concrete represents a great economic importance. With the depletion of aggregate resources in Algeria and the high cost of transportation, it becomes economic and environmental interests that could present the valorization of abundant local sands such as the dune sand for manufacturing of concretes. *Bederina et al.* [40] have studied the possibility of using local sand available in large quantities in sandcrete. This study showed that the correction of the granular distribution by means of mixing two local sands in predetermined proportions has allowed obtaining a more workable, more compact, and more resistant sandcrete. In concrete design, the dosage and fineness of aggregates have an important influence on quality of fresh and hardened properties of concrete. *Brouwers and Radix* [41] have found that the fine sand is useful component in optimizing the particle size distribution and thereby increasing the flowability, stability and mechanical properties of concrete mixes. *Kay et al.* [42] investigated the potential of using DS as fine aggregates in concrete. Results indicated that DS could be used as fine aggregate in concrete production. *Banfill et al.* [43] have also studied the effect of very fine sand dredged from river estuaries on concrete mixtures. It was found that as the sand content increases, the water required for a given workability increases and the strength development is not different than conventional concrete. *Laquerbe et al.* [44] studied the effect of using laterite gravel and DS as aggregates for concrete. The authors showed that, the laterite gravels can be used instead of basalt or limestone, and DS can serve as a substitute for seashore sand.

Bouziani et al. [45-49] have studied the properties of flowable concrete (FSC) made with DS. Test results show that an optimal content of dune sand, which makes satisfied fresh and hardened properties of FSC, is obtained. Bouziani [47] used a mixture design modelling approach to highlight the effects of river sand (RS), crushed sand (CS) and dune sand (DS) on flowability, passing ability, segregation and mechanical strength of SCC. The derived mathematical models make it possible to illustrate the variation of different responses in with respect to the proportions of RS, CS and DS. Results indicate that when flowability requirements are combined, proportions of DS and CS with RS must be below 0.24 and 0.6 respectively. Moreover, it is shown that passing ability can be satisfied by using a CS proportion above 0.3 in RS-CS system and above 0.65 in CS-DS system. On the other hand, proportions above 0.5 of CS in RS-CS system and above 0.2 of DS in RS-DS system are recommended to meet stability limits. Results also indicate that compressive strength days increased with the increase of CS proportion and decreased with the increase of DS proportion. Another experimental research on fresh and hardened properties of flowable sand concrete (FSC) reinforced by polypropylene fibers (PF) has been carried out by Bouziani et al. [48]. Results indicate that all studied mixtures have a pseudo-plastic behavior in fresh state. Results also confirmed that PF incorporation increases the viscosity and reduces free shrinkage of FSC. In terms of mechanical strength, results show that incorporating PF would enhance flexural strength. However, a reduction in compressive strength is observed.

R'mili et al. [50, 51] studied the incorporation of roller sand, crushed sand and desert sand in the composition the self-compacting concretes (SCC). Desert dune sand, which has a fine extra granulometry, and the crushed sand, which contains an important content of fines, can constitute interesting components for SCC. These sands, with different sizes, consist of several combinations of rolled sand (RS), crushed sand (CS) and desert sand (DS). The study examines the influence of the granular combination of sands on the characteristics in the fresh and the hardened state of SCC. The results of the experimental tests showed an improvement of the workability of the fresh SCC by combining the different sands. The addition of the DS to CS or to RS allowed to increasing the mixture viscosity, but decreased the mechanical strengths. Furthermore, the CS-RS combinations increased the compressive and the tensile strengths of the studied SCC. The optimized formulations of sands gave the highest performances of the SCC.

It should be noted that, no detailed investigation has been done to study the effect of combining different sand in binary and ternary system on some properties of self-compacting concrete. It is in this context that, the present work aims to study the effect of different types of sand fresh and hardened properties of SCC made with marble powder as cement replacement in one hand. In the other hand, recycling this waste powder, which is not used and can cause a very serious environmental problem.

In this regard, three types of sand with different origin and morphology are used; crushed sand (CS), dune sand (DS) and river sand (RS). Binary (CS+DS; CS+RS; RS+DS) and ternary (CS+DS+RS) system mixtures of proportions of these

sands were also used in this study. Tests used to evaluate the filling ability are slump flow and V-funnel tests. The passing ability was measured by L-Box and J-ring tests. The resistance to segregation was checked by GTM sieve stability test. Compressive strength were also determined at age of 28 days.

2. Materials and tests

2.1. Materials

The cement used in the present study was a CEM I 42.5. The chemical and physical properties of cement are given in Table 1. The waste marble powder (WMP) used in this study as cement supplementary material is a waste powder resulting from cutting, shaping and lustrating of the marble stones as shown in Fig 1. The chemical composition and physical properties of WMP are also given in Table 1. From this table, the WMP is mainly consisted of calcite about 56.01% with some traces of the quartz and dolomite as confirmed shown by of X-ray diffraction analysis presented in Fig. 2. Scanning electron microscopy (SEM) was performed to determine the surface characteristics of the WMP and typical image is presented in Fig. 3. As it can be seen, WMP presents angular shapes with rough surface texture. In order to determine particle size distribution of WMP and cement, laser distribution analysis was realized and the results are illustrated in Fig. 4. The results indicate that WMP is relatively finer than the cement, and about 70% of particles of WMP have a size less than 10 μm , and about of 40% of these particles are lower than 63 μm . A polycarboxylic-ether type superplasticizer (SP) with a specific gravity of 1.07 and a solid content of 30% was used.

Chemical composition (%)	Cement	Waste marble powder
SiO ₂	21.7	0.42
CaO	65.7	56.01
MgO	0.7	0.12
Al ₂ O ₃	5.2	0.13
Fe ₂ O ₃	2.7	0.06
SO ₃	0.6	0.01
K ₂ O	0.4	0.01
TiO ₂	0.21	0.01
Na ₂ O	0.7	0.43
Cl	0.01	0.03
Loss of Ignition	0.3	42.78
Physical properties		
Specific density	3.15	2.7
Fineness (m ² /kg)	300	360
Compressive strength at 28 days (MPa)	44	-

Table 1. Chemical composition and physical properties of cement and waste marble powder

1. táblázat Cement és márvány hulladék por kémiai összetétele és fizikai jellemzői

Fig. 1. Disposal of waste marble to the ground
1. ábra Hulladék márvány ártalmatlanítása

Fig. 2. X-ray diffraction of waste marble powder (WMP)
2. ábra Márvány hulladék por röntgendiffraktogramja

Fig. 3. SEM view of waste marble powder (WMP)
3. ábra Márvány hulladék por elektronmikroszkópos felvétele

Fig. 4. Particle size distribution of cement and waste marble powder (WMP)
4. ábra Márvány hulladék por és cement szemeloszlása

Continuously graded coarse aggregates (CA) (3/8 and 8/15 mm) were used in this study with a specific gravity and water absorption of 2.7 and 2.5% respectively. Various types of sand are used: river sand (RS) which is available natural source as shown in Fig. 5, crushed sand (CS) which is a waste of quarry stone crushing as seen in Fig. 6, and dune sand (DS) very available in the desert of Algeria as shown in Fig. 7. Mixtures of these sands in binary and ternary system are also used. The physical properties and sieve analysis results of these sands are given in Table 2 and Fig. 8 respectively. The maximum (D) dimension of RS, CS and DS sands were respectively 5, 4 and 0.63 mm. in order to determine the surface characteristics of the different sands, scanning electron microscope (SEM) was carried out and images of RS, CS and DS grains are given in Fig. 9. SEM investigations reveal the rounded shape of the RS and DS grains, and angular shape of CS grains. They show also the fineness and cleanness of DS compared to RS and CS, and the high filler content of CS. Moreover, X-ray diffraction analysis was performed; results are represented in Fig. 10. The X-ray diffraction analysis shows that RS and DS contain mainly the quartz (SiO_2) with some traces of calcite. However, CS contains the calcite (CaCO_3).

Fig. 5. Huge use of river natural sand (RS)
5. ábra Természetes folyami homok kitermelése

Fig. 6. Disposal of quarry crushed sand to the ground (CS)
6. ábra Zúzott bányahomok deponálása

Fig. 9. SEM views of different types of sand: (a) RS; (b) CS; (c) DS

9. ábra A felhasznált homokok elektronmikroszkópos felvételei

Fig. 7. Large quantities of dune sand in the desert of Algeria (DS)
7. ábra Algériai sivatagi dűne homok

Fig. 8. Particle size distributions of different types of sand (RS, CS, DS)
8. ábra A felhasznált homokok szemeloszlása

Properties	Sand type		
	CS	RS	DS
Specific gravity	2.68	2.67	2.65
Unit weight (kg/m^3)	1541	1758	1520
Fineness modulus	2.21	2.45	0.78
Sand equivalent (%)	71	87	83

Table 2. Physical properties of the used sands
2. táblázat A felhasznált homokok fizikai jellemzői

Fig. 10. X-ray diffraction of different types of sand: (a) RS; (b) CS; (c) DS
 10. ábra A felhasznált homokok röntgendiffraktogramjai

2.2. Mixture proportions

SCC mixes were made, which had total powder binder (cement + marble powder) content of 475 kg/m³. The coarse aggregates content was maintained at 31% by volume of cement for concrete and fine aggregates content at 50% by volume of mortar in concrete. The water to powder ratio (W/P) was fixed at 0.4 by weight with air-content being assumed to be 1%. SCC mixes were prepared with different types of sand: crushed sand, river sand, dune sand and binary or ternary sands. The SCC mixture proportions are summarized in Table 3.

2.3. Mixing procedure

The mixing procedure and time are very important, thus the mixing process was kept constant for all concrete mixtures. The batching sequence consisted of homogenizing the powder and aggregates for 30 sec in a rotary planetary mixer, then adding 70% of water and mixed for 1 min. Thereafter remaining water (30%) with SP was introduced, and the concrete was mixed for 5 min, then the mixing was stopped for 2 min and again the concrete was further mixed for 30 sec before it was discharged from the mixer.

2.4. Concrete testing

In this investigation, the slump flow test was used to evaluate the flow ability of self-compacting concrete in terms of mean spread diameter. The minimum value of self-compacting concrete to be 650 mm and a maximum of 800 mm for a fresh self-compacting concrete [52]. During the slump flow test, the time required to reach 50 cm diameter of slump flow is measured (T_{50}). The V-funnel test is used to determine the filling ability of the concrete. The time taken for the concrete to flow down is noted in seconds [53]. The maximum time that can be taken by a self-compacting concrete mix in V-funnel is 10 seconds. The passing ability was measured by L-Box test. The test was started by removing the control gate at once to allow the flow of self-compacting concrete through the horizontal obstruction in the box and then the ratio of H_2/H_1 were determined, if the concrete flows freely as water, at rest it will be horizontal and therefore the

Mix. N°	Mix. code	*(C+WMP) (kg/m ³)	CS (%)	CS (kg/m ³)	RS (%)	RS (kg/m ³)	DS (%)	DS (kg/m ³)	CA (kg/m ³)	SP (kg/m ³)	Water (kg/m ³)
SCC1	100CS	475	100	886	0	0	0	0	830	2.9	190
SCC2	100RS	475	0	0	100	886	0	0	830	4.2	190
SCC3	100DS	475	0	0	0	0	100	886	830	7.1	190
SCC4	75CS+25RS	475	75	665	25	222	0	0	830	2.9	190
SCC5	50CS+50RS	475	50	443	50	443	0	0	830	2.9	190
SCC6	25CS+75RS	475	25	222	75	665	0	0	830	2.9	190
SCC7	75CS+25DS	475	75	665	0	0	25	222	830	2.9	190
SCC8	50CS+50DS	475	50	443	0	0	50	443	830	2.9	190
SCC9	25CS+75DS	475	25	222	0	0	75	665	830	2.9	190
SCC10	75RS+25DS	475	0	0	75	665	25	222	830	4.2	190
SCC11	50RS+50DS	475	0	0	50	443	50	443	830	4.2	190
SCC12	25RS+75DS	475	0	0	25	222	75	665	830	4.2	190
SCC13	50CS+25RS+25DS	475	50	443	25	222	25	222	830	2.9	190
SCC14	25CS+50RS+25DS	475	25	222	50	443	25	222	830	2.9	190
SCC15	25CS+25RS+50DS	475	25	222	25	222	50	443	830	2.9	190

*(C+WMP): 90% Cement (C)+10% waste marble powder (WMP) CS: crushed sand; RS: river sand; DS: dune sand; CA: coarse aggregate; SP: superplasticizer

Table 3. SCC mixture proportions with different types of sand
 3. táblázat Öntömörödő betonok összetételei különböző homokok felhasználásával

Fig. 11. Slump flow of SCC with different types of sand
11. ábra Öntömörödő beton roskadási területe különböző homokok felhasználásával

Fig. 12. J-Ring Slump flow of SCC with different types of sand
12. ábra Öntömörödő beton blokkológyűrűs roskadási területe különböző homokok felhasználásával

Fig. 13. V-Funnel flow time of SCC with different types of sand
13. ábra Öntömörödő beton kifolyási ideje különböző homokok felhasználásával

Fig. 14. L-Box filling high H_2/H_1 ratio of SCC with different types of sand
14. ábra Öntömörödő beton L-doboz H_2/H_1 feltöltési hányadosa különböző homokok felhasználásával

Fig. 15. Passing mortar using sieve stability test (GTM) of SCC with different types of sand
15. ábra Öntömörödő beton szítastabilitási (GTM) vizsgálata különböző homokok felhasználásával

Fig. 16. Compressive strength at 28 days of SCC with different types of sand
16. ábra Öntömörödő beton nyomószilárdsága különböző homokok felhasználásával 28 napos korban

ration will be equal to unity. The minimum acceptable value is to be 0.8 [52]. J-Ring slump test was also used to evaluate the passing ability. The resistance to segregation was assessed by GTM sieve stability test. The minimum acceptable value is to be 15% [52].

For compressive strength tests, from each concrete mixture three prisms of 70×70×280 mm were cast. After removal from moulds, at 24 h of age, concrete specimens were immersed in water saturated with lime at 20 °C until the age of testing. The compressive test was conducted at the age of 28 and 90 days for the different mix proportions according to NFP 15-451 on the half samples obtained after the flexural test.

3. Results and discussion

3.1. Slump flow test

The results of slump flow are presented in Fig. 11. It is noted, that the slump flow values of all SCC mixtures are in the range slump flow values defined by the AFGC recommendations [53]. It is remarked an increase in the slump flow of SCC with mixture sand of RS+CS, this increase becomes very important

when the percentage of RS exceeds 50%. A decrease in slump flow was observed in SCC with binary mixture sand of CS+DS and RS+DS, this decrease also becomes very important when the DS percentage is very high. Therefore, the addition of dune sand up to 25% improves the slump flow of SCC. Beyond this content of dune sand, the slump spread decreases and does not meet the criteria for self-compacting concrete, and behaves like an ordinary concrete. R'mili et al. [50, 51] studied the effect of the incorporation of crushed sand and desert sand on the properties of self-compacting concretes. The results show that the workability parameters are improved when the crushed sand is partially replaced by desert sand (dune sand). A substitution rate of 15% gives good workability in terms of flow spreading and T_{50} flow time. Beyond this sand dune content these parameters decrease and do not meet the criteria of a self-compacting concrete.

From this, it can be concluded that the river sand has a beneficial effect on the slump spread, unlike the dune sand, which reduces remarkably the slump spread of SCC. The SCC highly proportioned in DS required at the same time important proportioning in SP and in water. This is due to the large finesses of these sands and to their need for water causing an increase in the viscosity. A demand for additional water is then necessary to improve the workability behavior of these SCC. Omar et al. [54] studied the influence of crushed sand substitution with different percentages of 25, 50 and 75% on the properties of concretes. They noticed that the use of crushed sand as fine aggregates improves the flow spreading of concrete due to the existence of fines. Gristada and Natt [55] used calcareous sand to improve the properties of self-compacting concretes. They noticed an increase in flow spreading with increasing dosage in calcareous sand. A substitution rate of 60% gave the best flow spreading of the used concretes.

3.2. J-Ring slump flow

The J-Ring spread results are shown in Fig. 12. It is noticed an increase in the J-Ring spreading in SCC with binary system mixture sand of CS+RS. On the other hand, a decrease in the spreading with the increase of the percentage of DS in SCC with binary sand and ternary system mixture of CS+RS+DS. This means that the high dosage of DS remarkably decreases the spread of SCC, hence the flowability of SCC. Nanthagopalan and Santhanam [57] studied the fresh properties of SCC prepared with crushed sand. They noted that the spread of SCC increases with the use of crushed sand compared to SCC made with natural sand. This is due to the increase in paste volume due to the existence of fines in the crushed sand [7].

3.3. V-funnel flow time

The results of the flow time using the V-Funnel test are shown in Fig. 13. This test indicates the filling capacity of mixture. The test of the flow through the funnel in V is a way to evaluate the viscosity and resistance to segregation of concrete. From Fig. 13, it can be noted that the values of the flow time through V- funnel are included in the interval (6-12 sec) proposed by Domone [48]. The addition of DS increases the flow time of SCC compared to that with RS, but the recorded values of

the flow time meet the recommendations of SCC production. R'mili et al. [50] have noted that the substitution of crushed sand by a sand dune in the composition of self-compacting concretes, allows to increasing the flow time to the V-funnel. This is explained by the increasing the viscosity up to a rate of 30%. Beyond this content, the SCC required an addition of water and superplasticizer to have self-placing properties [51]. One can say even with moderate dosages of DS that the measured flow time shows that incorporation of DS increases the viscosity of SCC and this is due to the increase of the specific surface area of fine aggregate of binary or ternary mixture. Gristada and Natt [55] have studied the properties of SCC with calcareous sand. They noticed that the flow time increases with the increase of the sand content. This is explained by the increase of the compactness of the mixture and consequently the increase of the viscosity.

3.4. L-box test

The results of variation of H_2 / H_1 using L-box test are shown in Fig. 14. It is seen that all results comply with the requirements of AFGC recommendations ($H_2 / H_1 > 0.8$) [53]. It is also noted a decrease in H_2 / H_1 in SCC with binary and ternary mixtures sands when the sand dune percentage is above 50%. The partial incorporation of DS in the mixtures increases the filling capacity of SCC, and therefore the mobility of SCC in confined areas. R'mili et al. [50] studied the effect of the incorporation of crushed sand and desert sand on the properties of self-compacting concretes. The results show that the L-box filling capacity is improved when the crushed sand is partially replaced by desert sand (dune sand). The H_2/H_1 ratio increases to a substitution rate of 15%. Beyond this sand dune content, this ratio decreases. For high amounts of DS, SCC behave like ordinary concrete. The use of binary and ternary mixtures sands improves the rheological properties of SCC. R'mili et al [50] have studied the effect of the incorporation of crushed sand and desert sand on properties of self-compacting concrete. The results show that the ability to fill in L-box is improved when the crushed sand is partially replaced by the desert sand. Kou and Poon [59] prepared a SCC with natural and recycled sand. The replacement rate of natural sand by recycled sand is 0, 25, 50, 75 and 100%. They noticed an increase in H_2 / H_1 ratio with increases in percentage of recycled sand.

3.5. Sieve stability test

Sieve stability test (GTM) results are shown in Fig. 15. It is noted that the percentages of mortar passing through the sieve are between 6 and 15% according to recommendations ENFRAC [52], except for SCC with DS as partial replacement of RS or CS in binary and ternary system mixtures, which are slightly over than the recommended values for SCC, but remain acceptable values. This is due to high percentage of DS used in blends, since the latter has a fine particle size that passes through the sieve with the amount of milt. Generally, the results obtained show that all SCC have good resistance to segregation and bleeding. Further, visual examination of SCC reveals that they are homogeneous and stable. The use of CS with RS or DS increases the volume of the paste and therefore improves the stability of the SCC.

3.6. Compressive strength

Fig. 16 shows the variation of the compressive strength of different SCC at 28 days. It can be noted that, the best strengths achieved after 28 days are obtained with SCC made with mixture sand of river and crushed sand. It is shown that the river sand has a beneficial effect on the compressive strength of SCC due to its continuous particle size. However, the strength gain for SCC containing crushed sand appears to be linked to the existence of limestone fines in sand in one hand, and in other hand the large size of the crushed sand. *Abdulghani* [60] studied the effect of sand size on the properties of self-compacting concretes. He noticed that, the resistance is not significantly affected by the size of fine aggregates. The sharp edges of the particles in crushed sand provide better bond with cement than rounded particles of river sand. *Shaik and Diami* [61] carried out a study on the mechanical properties of concretes made with industrial sand (crushed sand) and natural sand (river sand). They have demonstrated that industrial sand used as fine aggregates can significantly improve the mechanical properties of concrete. The crushed aggregates with angular shape confer a good bond granulate-cement compared to rolled aggregates. *Kothai and Malthy* [62] carried out a study on the influence of replacing natural sand with crushed sand on the mechanical strength of self-compacting concrete. They found that a substitution rate of natural sand by industrial sand or crushed of 30% gives good mechanical strength in terms of compressive, tensile and flexural strength. A reduction in the compressive strength was observed in SCC with binary and ternary mixtures of crushed- dune sand, river - dune sand and crushing- river -dune sand. This means that the dune sand decreases compressive strength of SCC due to its very fine particle size, high surface area and high porosity, which gives less compactness of SCC than those made with river and crushed sand [63, 64]. *R'mili et al.* [50] found that the partial substitution (30%) of crushed sand by desert sand (dune sand) in the composition of self-compacting concretes, contributed to the improvement of mechanical resistance. Beyond 30% substitution of dune sand resistances decrease, but they reach acceptable values compared to ordinary concrete.

3.7. Microstructure

Since the siliceous sand is inert, the increase in strength is obtained by densification of the matrix and the matrix-aggregate interface. In the case of sand limestone and silico-limestone, adds to the densification an interaction between the matrix and the aggregates, which gives good adhesion sand-cement paste and increases the strength. This is verified by the SEM examination of the samples, which shows crack propagation through the cement paste and aggregates. Fig. 17 represents SEM examinations of SCC with 100% RS, 100% CS and 100% DS respectively. The crack propagation is observed through the cement paste.

Fig. 17. SEM views of SCC with different types of sand: (a) 100% RS; (b) 100% CS; (c) 100% DS

17. ábra Öntömörödő beton elektronmikroszkopos felvételei különböző homokok felhasználásával, (a) 100% RS; (b) 100% CS; (c) 100% DS

Bellanger et al. [68] observed in this connection that the character of the fracture, in mortar or concrete, differed according to the type of aggregate: it is always intergranular in a siliceous concrete, it is intergranular in the case of hard limestone aggregates, and intragranular when the paste is less deformable than the aggregate. *Bachiorri* [69] has also observed changes in the mode of crack propagation in aluminous calcareous sand mortars. Different authors have studied the properties of calcareous aggregates in a cement matrix. *Husson* [70] has shown that limestone fines were active within a cement matrix and that they participated in hydration reactions by forming with others carboaluminates. To highlight this phenomenon, *Husson* [70] worked on calcite (98.6% CaCO_3) with a particle size slightly smaller than that of the binder. Other authors [70] have shown that the composition of the interfacial zone could be modified when the aggregate is reactive (e.g. calcite) by the formation of carboaluminates, calcium carbonate complexes, calcium hydroxide. Therefore, the surface of the aggregates was attacked by the formation of these compounds. Interface resistance tests

have shown that for these reactive aggregates, the fracture was farther away than at the surface of the aggregate. The further the breaking zone is from the aggregate, the higher the resistance at the interface [71].

Bellanger et al. [72] have demonstrated the contribution of these chemical interactions on the mechanical strength, both in flexural and compressive strength, on mortars or concretes based on calcareous aggregates compared to the same materials with siliceous aggregate. They have also shown, with a succession of charge-discharge cycles, that calcareous sand mortar and concrete have an almost perfect elastic character, that is to say that the deformations are quasi-reversible up to 80% maximum stress. Under the same conditions, siliceous concrete has shown irreversible deformations for much lower stresses.

4. Conclusions

The assessment of the behavior of SCC at fresh and hardened state leads to the followings:

- The use of binary and ternary mixtures sands improves the rheological and mechanical properties of SCC.
- At different contents of river and crushed sand, the rheological and mechanical characteristics are met and comply with recommendations of the manufacturing of SCC. However, the use of high dosages of sand dunes reduces the rheological parameters of SCC. Therefore, to meet the self-compacting properties, additional amounts of water and superplasticizer are strongly required.
- The best strengths are obtained for SCC made with crushed and river sand. This is due to the good size distribution of these sands. The mechanical strengths decreased by adding a high content of dune sand but they reach acceptable values.

Based on the obtained results, it can be argued that the use of locally available materials in the manufacturing of concrete can be an economic and technological important alternative in some developing countries. The partial incorporation of the sand dune in the composition of self-compacting concrete can provide a solution for some work in the southern regions of the country where this material is very abundant. Moreover, crushed limestone sands are interesting alternative source to replace the river sand (rolled) for making any kind of concrete.

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