KOMPEGE

IV. INTERNATIONAL EGE COMPOSITE MATERIALS SYMPOSIUM

PROCEEDINGS BOOK

6-8 September 2018

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Rasim İPEK

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PREFACE

It is our pleasure to welcome you to KOMPEGE 2018 (IV. International Ege Composite Materials Symposium) organized by Ege University Faculty of Engineering that took place on September 06-08, 2018 Izmir, Turkey.

The first KompEGE I (17-19 November 2011) and second KompEGE II (7-9 November 2013) and KompEGE III (5-7 November 2015) were held in Kusadasi organized by Ege University Faculty of Engineering.

The symposium provided a platform to bring together academicians, researchers, industrialists, practitioners and other related experts from home and abroad to share knowledge and experiences, which promoted intellectual and practical development in the all field of Technology, Engineering and Science.

KOMPEGE 2018 at the Bioengineering Department of Engineering Faculty at Ege University took place for three days, with more than 550 scientists including countries Japan, Germany, Greece, Iran, Poland, India and Turkey. They discussed current technology and science of composite materials and production.

In KOMPEGE 2018, 132 posters were presented while 173 oral presentations were discussed. In addition, 6 very special subject talks were done by invited speakers. Beside of this, 10 panellists discussed the current composite technology and related problems in two different panels.

Finally, on behalf of the KOMPEGE 2018 Organizing Committee, we would like to express our appreciation to all the participants for taking time out of your busy duties to attend the Symposium.

We would like to thank all academicians, researchers, industrialists, practitioners and other related experts. We would also like to thank our sponsors BMC Automotive Industry and Trade Inc. and IMS Polymers.

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CHARACTERISATION OF HIGH PERFORMANCE COMPOSITES WITH SPECIAL REFERENCE TO THE INTERFACE SUBSTRATE/RESIN MATRIX — NANO INTERFACE HAS MEGA ROLE IN THE COMPOSITES ARCHITECTURE.

Dr. Amir Hussain

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ABSTRACT

For high performance composites, a precise knowledge of the substrate surface is of immense importance. Inorganic as well as organic substrates are often pretreated -- plasma, corona, silane coupling agent etc. -- before an adhesive is applied for bonding. Topography, wettability, chemical functionality and cleanness of the surface play very important role in the quality of adhesion. Each of these 4 factors plays a crucial role and the contribution of these factors to the quality and durability of the end-product composite is additive.

For accurate characterisation of the surface, advanced analytical techniques like AFM, ESCA and TOFSIMS have proved to be of great benefit. These modern tools have gone a long way in providing an insight into the surface / interface of the bonded materials and the main cause of adhesion failure. Contamination is one of the main enemies in industrial bonding; ESCA and TOFSIMS have proved to be very effective to identify and combat the enemy. The properties profile of the composites are investigated with the help of thermo-mechanical techniques like DSC / DMA.

Failure analyses of composites conducted by Comtech over 10 years point out in over 75 % of studies to the interface.

NANOPARTICLE-WEBBED HYBRID HYDROGELS

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ABSTRACT

Recently hybrid hydrogels with new class of crosslinking system have been attracting considerable attention because of their unique properties and wide range applicability in various fields. We have developed nanoparticle-webbed hybrid hydrogels in which the polymer network was multiply-crosselinked with silica nanoparticles (Web-GEL). This hybrid hydrogels were prepared in a facile manner involved simple mixing of an aqueous solution of a water-soluble copolymer having reactive side chains with an aqueous suspension of silica nanoparticles. The properties of hybrid hydrogels can be tuned very easily only by modulating the properties of copolymer (chemical structure and concentration) and nanoparticles (concentration). In this presentation, we will describe the following topics of the hybrid hydrogels.

1. Preparation of Web-GEL and their versatility.
2. Mechanical and swelling/de-swelling properties of Web-GEL.
3. Thermo-responsible Web-GEL and their application for drug release.
4. Preparation of microspherical hybrid hydrogels.

It is expected that the hybrid polymer hydrogels prepared according to the strategy presented in this paper will find applications in various fields such as the medical and pharmaceutical sciences and environmental and industrial technologies.

Keywords: Multiple-crosslinking / Inorganic nanoparticles / Polymer network structure / Gel particles

COMPOSITES IN NEW APPROACHES FOR SELECTIVE SEPARATION

Marek BRYJAK

ABSTRACT

A demand for new materials dedicated to separation processes has been developed last decades greatly. The supply cannot be completed by delivery of brand new separators as there is observed a stabilization in their production. History of polymers is the best example of that phenomenon - production of these commodities reached the value of 350 million metric tons several years ago and has not exceeded so far. In such situation, the search has focused on composites that merges properties of few components and creates new entities that, due to synergy effect, offer interesting features.

The lecture will be illustrated with examples showing the use of polymer composites in preparation of membranes, electrodes and sorbents. In the first case – coverage of membrane surface with grafted polymer and/or nanoparticles allowed to change surface character and made it hydrophobic or hydrophilic. The second approach for membrane modification was formation of stimuli responsible membranes that allowed to control permeation of lithium ions. In the case of electrodes preparation, composites of manganese oxide with titanium oxide will be presented for selective separation of lithium salts in the ion-pumping systems. Finally, preparation of core-shell sorbents useful for selective recovery of noble metals will be presented.

NANO-ENGINEERED COMPOSITE ELECTROSPUN POLYMERIC MEMBRANES FOR DESALINATİON AND WATER TREATMENT

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ABSTRACT

Composite fibrous structures with nano-scale diameters offer a multitude of fascinating features, including large specific area and promising mechanical behavior for a wide range of applications. The large specific area also gives them high functionalization ability. There are different methodsfor generating composite nano-fibrous structures. However, among them electrospinning is rapidly emerging as a simple and versatile technique in which careful control of operating conditions and polymer solution properties enables the production of highly porous structures of nano-fibers. Electrospinning is a very promising technique by which polymer fibers with diameters ranging from a few nano-meters to several micro-meters can be produced using an electrostatically driven jet of polymer solution. Compared to conventional techniques for membrane fabrication, such as phase inversion, electrospinning allows the formation of three dimensional interconnected pore structure with uniform pore size and porosities ≥90%. As a result, nano-engineered composite fibrous membranes are increasingly being applied to many water treatment applications such as membrane distillation (MD) and pre-treatment of feed prior to reverse osmosis (RO) or nanofiltration (NF) processes by the removal of contaminants. In this presentation, the preparation and application of nano-engineered composite electrospun membranes for desalination and water treatment purposes are discussed.

NANOCOMPOSITE THIN FILMS AND COATINGS

Assoc. Prof. Cenk Aktas
Christian-Albrechts-University
Saarland University

ABSTRACT

For future and as well as today`s technologies it is difficult to satisfy sophisticated requirements by using “a single material”. Nanocomposites, which are basically composed of a host matrix and nanoscaled filler material(s), have emerged alternatives to overcome limitations of conventional single phase materials. In surface technologies used in wide application areas ranging from mechanical components to solar energy and from electronics to medicine, nanocomposite thin films and coatings provide various advantages.

This lecture will cover a brief review on functional nanocomposite thin films and coatings. In the first part basics of such surfaces including synthesis any analysis approaches will be briefly introduced. In the second part some case studies will be provided by giving examples of polymer-metal and metal-metal oxide nanocomposite thin films. The importance of interface and surface modification in nanocomposite and as well as other composite technologies will be discussed. Afterwards applications of nanocomposite thin films and coatings for several sectors including the aerospace, automotive, electronics and biotechnology industries will be presented.

BIOLOGICAL INTERACTIONS WITH MATERIAL SURFACES

Yannis Missirlis,
University of Patras, Greece

ABSTRACT

When materials interact with biological entities, i.e. biomolecules, cells, bacteria, tissues, there is a considerable dynamic interaction resulting in responses of the biological part, partially determined by the surface properties of the materials.

The composition of the non-living material surface determines its physicochemical properties, including chemical groups, charge distribution, topographical features, mechanical properties, all of which are interrogated by the cells and bacteria that come into contact with it. The system (bio-nonbio) is dynamic, not only on its own, but because usually it is under external force fields, such as flow conditions.

A cascade of information at the biointerphase, part of which is referred as mechano-transduction, reaches into the nucleus of the cells and initiates a series of reactions, including gene expressions. In this presentation examples will be given on the role of topography, chemistry and mechanical signaling, emanated from the material surface , on the cellular and bacterial responses.

THE ROLE OF MATRIX STRENGTH ON FLEXURAL BEHAVIOR OF HIGH TENACITY POLY-PROPYLENE FIBER REINFORCED ENGINEERED CEMENTITIOUS COMPOSITES (HTPP-ECC)

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ABSTRACT

Cement based composites such as concrete exhibit low flexural strength and are vulnerable to cracking due to their brittle structure. To overcome this weakness, different types of fibers are used as reinforcement. In this study, the effect of matrix strength on flexural performance of High Tenacity Poly-propylene (HTPP) fiber incorporating Engineered Cementitious Composites (ECC) has been investigated. Matrices with two different strengths were prepared. While the first matrix was consisted of a composition of cement and limestone (strong matrix); second matrix was consisted of 50% of fly ash substituted with cement (weak matrix). 25x60x300 mm sized samples were prepared from each matrix and water cured until testing. Four point flexural tests were conducted at 28 and 90 days. Strong matrix presented more favourable results in terms of flexural performance within the scope of this study. The first crack and flexural strengths of the composites prepared with the strong matrix were 2.45 and 7.91 MPa and for weak matrix these values were 1.06 and 4.01 MPa at 28 days, respectively. Also, the deflection capacity and toughness values of the composites prepared with the strong matrix were calculated as 6.52 mm and 6160 N.mm and for weak matrix they were 4.4 mm and 1901 N.mm at 28 days, respectively. At 90 days the enhancement for first crack strength, flexural strength, deflection capacity and toughness were 90%, 33%, 22% and 57% for strong matrix and %328, %99, %10 and %133 for weak matrix, respectively.

KEYWORDS: Matrix strength, ECC, HTPP, polymeric fiber, flexural strength

1. INTRODUCTION

Conventional concrete is the most common building material due to the availability of low cost raw materials used in its production process and ease of application. The most important advantage of concrete is its high compressive strength. However, concrete has very low tensile and flexural strengths compared to its high compressive strength. For this reason, it easily cracks under tensile and flexural stresses and loses its load carrying capacity (Daniel and Shah, 1994).

Maalej and Li (1994), noted that there were three types of tensile failure modes in cementitous composites: brittle, quasi-brittle and ductile behaviors. Brittle behavior can be observed in cement paste composites whereas concrete and most fiber-reinforced cementitious composites perform quasi-brittle behavior. At brittle behavior there is a sudden drop after first cracking at the stress-strain curve (Figure 1A). Quasi-brittle behavior can be seen at Figure 1B with strain softening after the first cracking. Ultimate tensile strength is equal to first crack strength at both brittle and quasi-brittle composites. Ductile behavior which is represented with C curve at Figure 1 can be characterized by strain hardening behavior after first cracking. These composites are called as strain-hardening cementitious composites and their ultimate strength is higher than their first crack strength. Engineered Cementitious Composites (ECCs) are unique kind of strain hardening cement-based composites produced by using a moderate volume of polymeric fiber (2% in general) (Li et al., 2003).

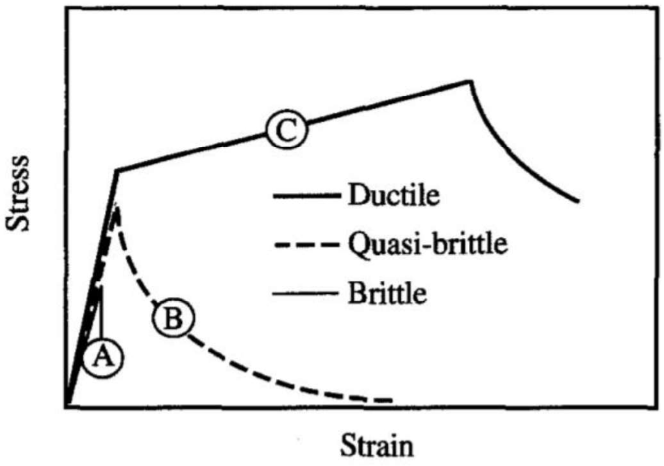

Figure 21. Three types of failure modes on cementitious materials

ECC is designed to exhibit multiple cracking behavior under flexural and tensile loads. At this point, composites with strain capacity 4% and very high toughness values can be produced (Li and Kanda, 1998). ECC also limits the crack width by increasing the number of cracks in the matrix due to the bridging effect of the polymeric fibers. By this way it is an ultra-ductile material that exhibits strain hardening under tensile loads (Fukuyama and Mikame, 1998). The multiple-crack behavior occurs when the load is transferred from cracked section to the other sections by the fibers. This behavior continues until the bridging capacity of fibers at one of the cracked section exceeded (Lin et al., 2014). Polyethylene (PE) was one of the first fiber type used in ECC (Lin et al., 2014). Polyvinyl alcohol (PVA) fibers have been preferred instead of PE to decrease the cost of production (Yang, 2008). Because of their high hydrophilic surface structure, PVA tend to break under tension loads when they used in ECC (Redon et al., 2001). Thus their performance is not fully used if their surface structure is not modified by oiling (Li, 1998). Recently, a new polymeric fiber named as high tenacity polypropylene (HTPP) is used successfully for producing the ECC including various matrices (Felekoğlu et al., 2014; Tosun-Felekoğlu et al., 2017; Gödek et al., 2017; Keskinateş and Felekoğlu, 2018). In order to facilitate multiple-cracking behavior of ECC fracture toughness of matrix should also be designed by taking the fiber properties into consideration (Li et al., 1995).

In this study, the effect of matrix strength to the flexural behavior of high tenacity polypropylene (HTPP) fiber reinforced ECC was investigated by using two different matrix type (strong and weak matrices). Four-point bending test were conducted to examine the flexural performances of composites prepared by using strong and weak matrices at both 28 (short term) and 90 (long term) days.

2. MATERIALS AND EXPERIMENTAL METHOD

CEM I 42.5R type cement is used in experiments and its physical and chemical properties were presented at Table 1. Limestone powder is used as micro-aggregate which has a specific weight of 2.69. F type fly ash is used in order to obtain different type of matrices. Chemical analysis of the fly ash is shown at Table 2. Polycarboxylate based super plasticizer is used in mixtures. Alkali resistant HTPP fiber is used as reinforcement and its properties were represented in Table 3.

Table 9. Physical and chemical properties of cement

Chemical Analysis (%)		Compressive Strength (MPa)	
SiO_2	18.81	2 Days	29.90
Al_2O_3	4.65	7 Days	43.30
Fe_2O_3	3.33	28 Days	52.80
CaO	63.58		
MgO	1.30	**Physical Properties**	
Na_2O	0.48	Specific gravity	3.10
K_2O	0.82	Blaine specific surface area (m^2/kg)	320
SO_3	3.47	Volume consistency (mm)	0.50
Cl	0.007	Initial setting time (min)	160
Free CaO	1.71	Final setting time (min)	265

Table 2. Physical and chemical properties of fly ash

Component	Chemical Analysis (%)	Component	Chemical Analysis (%)
SiO_2	55.49	CaO	2.43
Al_2O_3	18.72	MgO	4.57
Fe_2O_3	10.02	Na_2O	0.51
K_2O	1.66	Loss on ignition	1.3
SO_3	0.38	Free CaO	0.17

Table 3. Physical properties of HTPP fiber

Specific gravity	Length (mm)	Diameter (µm)	Tensile strength (MPa)	Elastic modulus (GPa)	Elongation at rupture (%)
0.91	10	12	850-900	6	21

Two types of matrices were prepared with HTPP fiber and their mixture proportions were presented in Table 4. Weaker matrix incorporating fly ash and was labeled as WM whereas strong matrix was called as SM. Mixtures were prepared by a Hobart mixer. It has three different mixing sequence as 56 rpm (slow), 104 rpm (medium) and 185 rpm (high). Dry ingredients were mixed for 1 minute in slow speed than water was added and mixed 1 more minute at medium speed. Finally, HTPP fibers and super plasticizer were added and mixed 5 min at high speed. Mixtures were molded into 25x60x300 mm prismatic molds and covered with plastic bag in order to prevent plastic shrinkage cracking. After a period of one day, specimens were demolded and cured in water tank for 28 and 90 days.

Table 4. Mix proportions for SM and WM

(kg/m^3)	**SM**	**WM**
Cement	854	378
Limestone powder	854	757
Fly ash	0	378
Water	380	399
Super plasticizer	16,8	12
HTPP fiber	18	18

Flexural tests were conducted with the four point bending test machine which had 6 kN capacity load cell. Test machine was at deformation control mode and rate was 0.5 mm per min and span length was 260 mm. Load-deflection curves were plotted by the test values. The very first breaking point of linearity at curves are taken into account as first crack strengths. Maximum flexural strength is calculated with the maximum point on curves and deflection value corresponding to that point also showed the deflection capacity of that sample. First crack and flexural strengths are calculated with PL/bh^2 formula, here L is span length, b is cross section width, h is cross section height and P is first crack load for first crack strength or maximum load for flexural strength. Toughness values are computed by the area under the curve, which was between the first crack load and maximum load points. Crack number analyses are also conducted on samples after the flexural tests with hand-type optical microscope.

3. MECHANICAL PERFORMANCES OF THE COMPOSITES

3.1 Discussion of Load-Deflection Curves

Load-deflection curves of SM and WM are shown in Figure 2 and 3, respectively. It was clear that the load carrying capacity of SM was better than WM both in short and long terms. Also aging enhanced mechanical properties of composites incorporating both matrices. Flexural performance enhancement was more apparent at WM. The possible reason is the late pozzolanic reaction process of fly ash with hydrated lime from cement, which contributes to the interfacial bonding between cement paste and polymeric fiber.

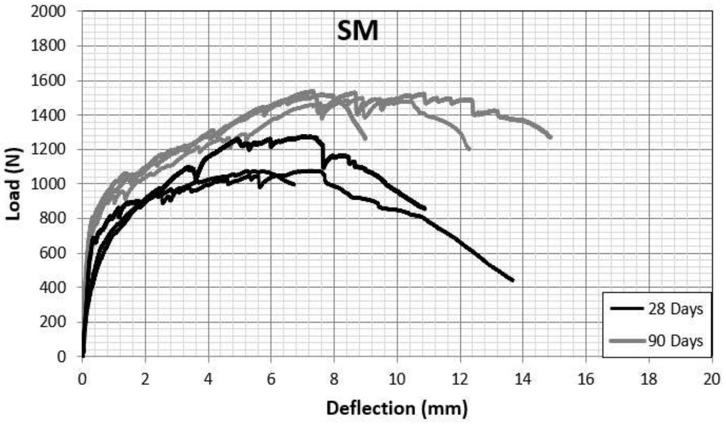

Figure 2. Load-deflection curves of SM

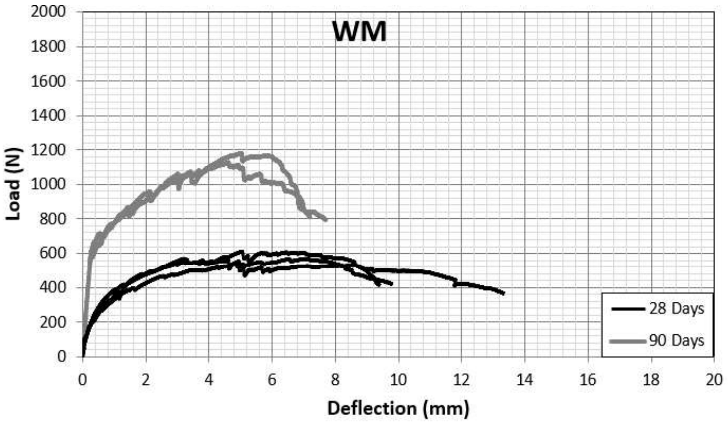

Figure 3. Load-deflection curves of WM

3.2. Discussion of First Crack and Flexural Strengths

The first crack and flexural strength values, which were obtained from load-deflection curves, are presented in Figure 4. Although the first crack strength of WM was lower than SM on 28 days, there were slightly no difference at long term. The flexural strength values were higher at both short and long terms for each series. The positive effect of curing was more obvious in WM than SM. When 90 days and 28 days of flexural performances were compared, there were 90% and 33% increase at first crack and flexural strengths of SM, respectively. This increment was 327% and 99% for first crack and flexural strengths of WM series. This result confirmed that bonding between fiber and matrix can be significantly improved at later ages if fly ash is used.

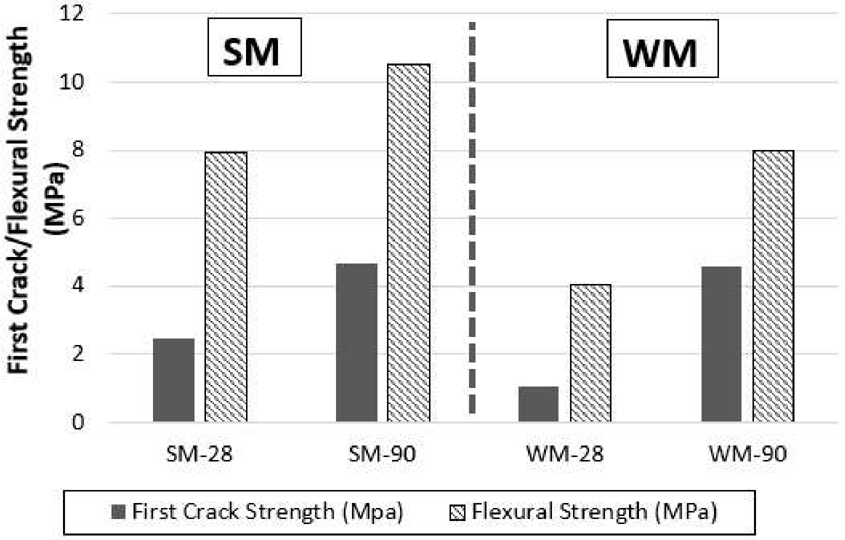

Figure 4. First crack and flexural strength values

3.3. Discussion of Toughness and Deflection Capacity

The toughness-deflection capacity and crack number-deflection capacity values of composites are shown in Figure 5 and 6, respectively. It was seen that both toughness and deflection capacity values were increased thorough the time (Figure 5). The toughness values of SM were 6160 and 9369 N.mm, on 28 and 90 days, respectively. These values were 1901 and 4424 N.mm for WM. The improvement of toughness and deflection capacity were more distinct for WM. Those changes in toughness and deflection capacity of WM thorough aging were 133% and 10% whereas they were 57% and 22% for SM, respectively.

Increased crack number value let the SM deform more easily and thus deflection capacity was also increased thorough the time. For ECC design, a brittle matrix is favorable to initiate cracking. From this point SM is more brittle at later ages and more suitable for multiple cracking compared to WM. Highest crack number values were obtained from SM at 90 days.

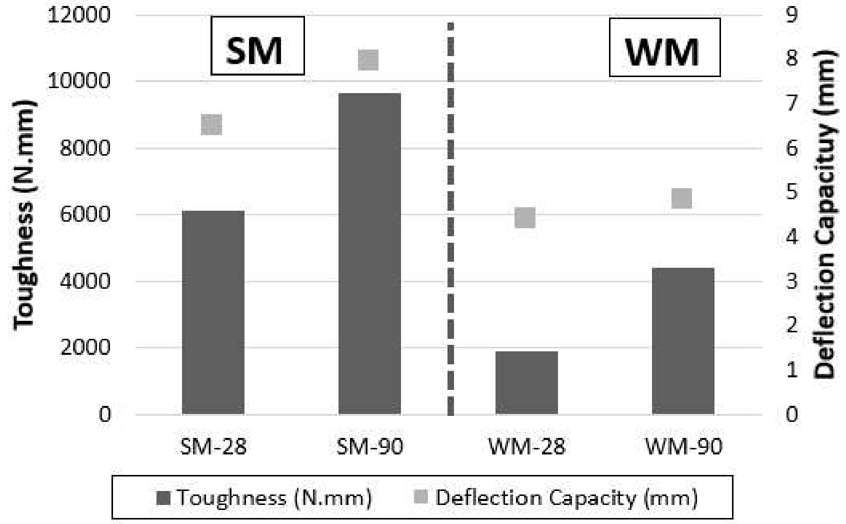

Figure 5. Toughness and deflection capacity values

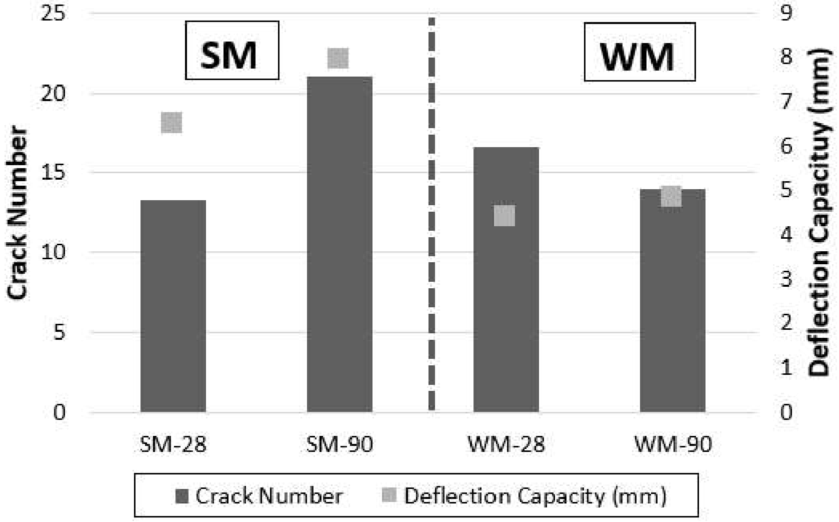

Figure 6. Crack number and deflection capacity values

4. CONCLUSION

The results of this experimental study showed a strong matrix (SM) which is more brittle at later ages compared to weak matrix (WM) is more appropriate for HTPP-ECC design with improved flexural performance. Multiple cracking performance of SM is also improved at 90 days.

Aging has a significant impact on composites flexural performance if fly ash is employed in mix design. The possible reason is the late pozzolanic reaction process of fly ash with hydrated lime from cement, which contributes to the interfacial bonding between cement paste and polymeric fiber. Except the deflection capacity, the improvement percentage increment of all mechanical properties (first crack strength, flexural strength and toughness) of WM composites were higher than composites with SM. As a suggestion, longer testing periods up to one year can be performed in order to observe if the flexural performance of fly ash incorporated matrix is further improved or not.

REFERENCES

Daniel, J. I., & Shah, S. P. (1994). Fiber reinforced concrete: developments and innovations. American Concrete Institute.

Felekoglu, B., Tosun-Felekoglu, K., Ranade, R., Zhang, Q., & Li, V. C. (2014). Influence of matrix flowability, fiber mixing procedure, and curing conditions on the mechanical performance of HTPP-ECC. Composites Part B: Engineering, 60, 359-370.

Gödek, E., Felekoğlu, K. T., Keskinateş, M., & Felekoğlu, B. (2017). Development of flaw tolerant fiber reinforced cementitious composites with calcined kaolin. Applied Clay Science, 146, 423-431.

Keskinateş, M., & Felekoğlu, B. (2018). The influence of mineral additive type and water/binder ratio on matrix phase rheology and multiple cracking potential of HTPP-ECC. Construction and Building Materials, 173, 508-519.

Li V. C. (1998) Engineered Cementitious Composites (ECC) – tailored composites through micromechanical modeling, Fibre reinforced concrete: Present and the future. In: Banthia N, Mufti A, (eds.), Canadian Society of Civil Engineers, (64–97).

Li, V. C. & Kanda, T. (1998). Innovations Forum: Engineered cementitious composites for structural applications. Journal of Mat. in Civil Eng., 10 (2), 66-69.

Li, V. C. (2003). On engineered cementitious composites (ECC). Journal of advanced concrete technology, 1(3), 215-230.

Li, V. C., Fukuyama, H., & Mikame, A. (1998). Development of Ductile Engineered Cementitious Composite Elements for Seismic Structural Applications.

Li, V. C., Mishra, D. K., & Wu, H. C. (1995). Matrix design for pseudo-strain-hardening fibre reinforced cementitious composites. Materials and Structures, 28(10), 586-595.

Lin, Y. W., Wotherspoon, L., & Ingham, J. M. (2014). Tensile properties of an engineered cementitious composite shotcrete mix. Journal of Materials in Civil Engineering, 27(7), 04014205.

Maalej, M. & Li, V. C. (1994). Flexural/tensile-strength ratio in engineered cementitious composites. Journal of Materials in Civil Engineering, 6 (4), 513-528.

Redon, C., Li, V. C., Wu, C., Hoshiro, H., Saito, T., & Ogawa, A. (2001). Measuring and modifying interface properties of PVA fibers in ECC matrix. Journal of Materials in Civil Engineering, 13(6), 399-406.

Tosun-Felekoğlu, K., Gödek, E., Keskinateş, M., & Felekoğlu, B. (2017). Utilization and selection of proper fly ash in cost effective green HTPP-ECC design. Journal of Cleaner Production, 149, 557-568.

Wang, S., & Li, V. C. (2007). Engineered cementitious composites with high-volume fly ash. ACI Materials journal, 104(3), 233.

Yang, E. H. (2008). Designing Added Functions in Engineered Cementitious Composites.