Influence of nanosilica, metakaolin and Polypropylene Fiber on dynamic and physicomechanical properties of Portland cement mortar

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Abstract. This study presents an experimental research conducted to inspect the impact of partial substitution through the usage of nano silica (NS) and metakaolin (MK) on cement mortars (CMs). Besides, the effect of the additive usage such as polypropylene (PP) on the dynamic and physicomechanical properties of CMs as single and combined effect. CM was formed through the usage of different substitution ratios of nano silica varying from 2 to 6% and metakaolin varying from 10 to 30 wt %, by cement weight, where the considered content for PP fiber was at 0.2%. Scanning electron microscopy (SEM), ultrasonic pulse velocity (UPV), flexural strength, and Compressive strength analysis are demonstrated in this paper. Results illustrated that, physicomechanical and dynamic properties of CMs positively enhanced as a result of using a mixture of PP, nano silica, and metakaolin. The CMs that included 0.2% PP, 4% NS, and 20% MK, showed the highest impact on physicomechanical properties compared to other mortar specimens.

1. Introduction

The occurrence of phenomena and structural elements in nano and micro scale affects the concrete mechanical behavior. So nanotechnology can be used in order to enhance characteristics of material’s bulk through modifying the concrete molecular structure. Also, nanotechnology can enhance the concrete sustainability, durability, volume stability, and mechanical performance. Recently, concrete materials unprecedented uses have been emerged as the cement and concrete long-lasting products, high-performance and cost-effective have been developed due to the impact of nanotechnology usage. The nanomaterials is characterized by the ability to provide mechanical reinforcement for structural materials based on cement which is considered from the most desired nanomaterials characteristics in construction sector. Three main advantages for nanomaterials usage are recognized. Firstly, the reduction in the duration of construction is observed due to the production of high-strength concrete accompanied by less curing time [1]. Secondly, the reduction in the cement quantity which is required
The additives performance within conjunction accompanied by PP fiber was not fully reported even though various cement-based materials aspects that include PP fibers and by-product materials was investigated. Particularly, the impact of PP fiber as materials that can enhance the toughness on the workability as well as MK and NS impact needed a detailed study. Besides, mortar durability properties and pore structure is considered in need of further detailed study.

This aim of the research to inspect the combination usage of NS/MK cements substitution materials and PP fibers (as addition) as well as considering their role on the resulted CMs dynamic and physicomechanical characteristics. The optimum percentages for fibers and mixtures within mortars in concrete to reduce the construction materials cost and the environmental effect, in addition, obtaining similar strengths. Thirdly, manufacturing of high-strength concrete for a certain application is considered as another advantage. The nano-sized solid particles mainly impact cementitious based materials performance such as the porosity of nano-sized within the interfacial transition zone between aggregate particles and cement, or calcium–silicate–hydrates particles (C–S–H). Typical characteristics influenced by voids or particles of nano-sized are steel-bond, shrinkage, durability, and strength [2]. The spaces between C– S–H gel particles can be filled by a nano-filler which is SiO2 Nano-particles (NS). Moreover, a high matrix densification was formed due to the increase in of C–S–H amount during the reaction of pozzolanic accompanied by calcium hydroxide that causes improvement in the material durability and strength. The nano-particles addition changes hardened and fresh and state properties, even in comparison with additions of conventional mineral according to previous research [3-9]. C3S hydration process was affected by amorphous silica colloidal particles [4]. Nano-silica reduced the mortar setting time in comparison with silica fume (SF) [5, 6] besides, the reduction in segregation and bleeding water during enhancing the admixtures cohesiveness within the fresh state [7]. The combination accompanied by ultra-fine fly ash ensures the performance improvement compared to that accomplished by the usage of silica fume lonely [8]. Also, the concrete or mortar compressive strength accompanied by silica fume was enhanced compared to the formula in the absence of the addition [9].

Recently, the introduction of highly effective and active pozzolan such as metakaolin has been recognized as a partial substitution for cement within concrete which is considered as ultrafine material that manufactured through kaolin precursor dehydroxylation by heating within temperature range of 700–800 °C [10,11]. At ambient temperature, CSH gel was formed due to the reaction of metakaolin which is considered as a silica-based product and Ca (OH)2. In addition, alumina which was presented in metakaolin formed a reaction with CH which generated additional alumina-containing phases whereC3AH6, C2ASH8, and C4AH13were included [12,13]. A significant enhancement in the early strength was observed due to the metakaolin incorporation within concrete [14]. Metakaolin enhances concrete resistance against alkali-silica reaction [15], and its impact on sulfate resistance grows with the increment of the cement substitution portion by metakaolin [16]. As high-reactivity metakaolin is introduced to the admixture, high-performance steel fiber-reinforced concrete (HPSFRC) toughness or energy absorption grows .Thus, the usage of high-reactivity metakaolin concrete is considered as added value for applications that needs high toughness and improved durability[17].Nevertheless, the water demand increases as the substitution amount of metakaolin increases according to other research. The need of water could be overcome through the addition of water reducer to preserve the flow characteristics and workability [18]. In this article, polypropylene (PP) fiber was utilized as another supplementary cementitious materials (SCMs).

Generally, in concrete construction, PP and steel fibers were considered as the most common utilized material [19,20]. At low volume portions (e.g., smaller than 0.3%), PP fibers are utilized within various applications. For instance, controlling reinforcement of shrinkage control reinforcement for concrete members is considered as one of the applications [21]. The fiber-reinforced concrete (FRC) mechanical characteristics was investigated by a lot of researchers especially concerning the hybrid usage of PP together accompanied by other fibers, for example the carbon/glass fibers, glass/PP fibers, or carbon/PP fibers mixtures. Nevertheless, combination of steel/PP FRC was studied in the most research [22]. The additives performance within conjunction accompanied by PP fiber was not fully reported even though various cement-based materials aspects that include PP fibers and by-product materials was investigated. Particularly, the impact of PP fiber as materials that can enhance the toughness on the workability as well as MK and NS impact needed a detailed study. Besides, mortar durability properties and pore structure is considered in need of further detailed study.

This aim of the research to inspect the combination usage of NS/MK cements substitution materials and PP fibers (as addition) as well as considering their role on the resulted CMs dynamic and physicomechanical characteristics. The optimum percentages for fibers and mixtures within mortars
were figured out through the hardened concrete experiments such as ultrasonic pulse velocity test, flexural strength, and compressive strength. A better indication for the impact of studied materials could be obtained through the usage of mortar instead of concrete within this study due to the material behavior of mortar which is considered as straightforward. For example, the ability to control experimental tests on mortar is more compared to those on concrete [23]. Most of the observations that was concluded from CM within this research can be applied to concrete that owns coarse aggregates as a supplementary stage.

2. Experimental program

2.1. Materials

2.1.1. Cement. Misr Beni-Suef Company (Beni-Suef city, Egypt) is considered as a producer for the Ordinary Portland cement (OPC) type I (42.5N), which is recognized as the used cement in this paper. A number of tests are carried out on a cement specimen to guarantee testing quality of final setting time, initial, soundness of cement, fineness, and specific weight. According to these tests result, the cement specimen physical characteristic and chemical composition are shown in tables 1 and 2.

Table 1: Physical properties of cement.

| Property          | Specific gravity | Fineness cm²/g | Initial setting time minutes | Final setting time minutes | Soundness mm | Compressive strength Kg/cm² |
|-------------------|------------------|----------------|------------------------------|----------------------------|--------------|----------------------------|
| Result            | 3.15             | 2700           | 85                           | 180                        | 1            | 202 308 438                 |

Table 2. Chemical composition of the cement.

| Oxides | Wt,(%) |
|--------|--------|
| SiO₂   | 21.16  |
| Al₂O₃  | 5.50   |
| Fe₂O₃  | 3.21   |
| MgO    | 0.69   |
| CaO    | 63.40  |
| SO₃    | 2.40   |
| K₂O    | 0.50   |
| Na₂O   | 0.10   |
| F.L.   | 2.70   |
| LOI    | 2.30   |

2.1.2. Fine aggregates. In this study, sand was utilized and undergone the tested Following ASTM C128 where the sand physical characteristics is given in table 3.

Table 3: Standard sand physical properties.

| Property          | Specific gravity | Bulk density kg/m³ | Percent of Clay and other Fine Materials |
|-------------------|------------------|--------------------|-----------------------------------------|
| Result            | 2.65             | 1650               | 0%                                       |

2.1.3. Metakaolin. The Physical properties of metakaolin is shown in table 4 where metakaolin is characterized by 3 μm mean particle size and 99.9% particles <16 μm. The metakaolin chemical analysis is shown in table 5.

Table 4: Physical properties of metakaolin.

| Property          | Specific gravity | Bulk density kg/m³ | Physical form | GE Brightness | Color   |
|-------------------|------------------|--------------------|---------------|--------------|---------|
| Value             | 2.57             | 0.4                | Powder        | 80           | Off-white |

Table 5: Chemical analysis of metakaolin.

| Oxides | Wt,(%) |
|--------|--------|
| SiO₂   | 51.52  |
| TiO₂   | 51.52  |
| Al₂O₃  | 40.18  |
| Fe₂O₃  | 1.23   |
| MgO    | 0.12   |
| CaO    | 0.0    |
| SO₃    | 0.53   |
| K₂O    | 0.08   |
| Na₂O   | 12.01  |
| LOI    | 12.01  |
2.1.4. Nano-silica. In this study, the used nano silica was produced at the laboratories of Beni-Suef central. Nano-silica (NS) physical and chemical characteristics are illustrated in tables 6 and 7, respectively. Figure 1 shows the TEM and SEM micrographs of nanomaterials particle of NS.

**Table 6:** Nano-silica physical properties.

| Property                  | Particle size (μm) | Bulk density, kg/m³ | Specific gravity | Specific surface area (m²/kg) | Color      |
|---------------------------|--------------------|---------------------|-----------------|------------------------------|------------|
| result                    | 7.00               | 345                 | 2.15            | 17.8x10³                     | Light gray |

**Table 7:** Chemical properties of nano-silica.

| Oxides      | Wt(%) | SiO₂ | TiO₂ | Al₂O₃ | Fe₂O₃ | MnO | MgO | CaO | P₂O₅ | K₂O | Na₂O | LOI |
|-------------|-------|------|------|-------|-------|-----|-----|-----|------|-----|------|-----|
| SiO₂        | 99.65 | 0.02 | 0.01 | 0.012 | <0.01 | <0.01| <0.01| <0.01| <0.01| <0.01| <0.01| 0.25|

**Figure 1.** TEM and SEM images of NS

2.1.5. Superplasticizer. In this research, the usage of superplasticizer which is chemical mixture that is characterized by a modified polycarboxylates high-range water-reducing is studied following (types F) ASTM C494. The total performance is controlled by chemical mixture which permits delayed absorption of cement particles and spread them. A concrete with a high quality is produced through the usage of superplasticizer of high-range water reducer through the strength incremental. Table 8 illustrates superplasticizer properties [19].

**Table 8:** Technical data properties of the superplasticizer.

| Form                                   | Appearance       | Density (kg/liter) | pH value |
|----------------------------------------|------------------|---------------------|----------|
| Aqueous solution of modified polycarboxylates | Brown liquid     | 1.185               | 4.5-4.9  |

2.1.6. Polypropylene fibers (pp). Polypropylene fibers with the diameter and length of 0.019 and 12 mm, respectively, were used within the study. The fibers properties and the geometry are given in figure 2 and table 9, respectively.
Figure 2: Shape and dimension of polypropylene fiber

Table 9: Properties of polypropylene fiber.

| Property | Shape of fiber | Length l (mm) | Diameter d (mm) | Aspect ratio L/d | Density (g/cm³) | Elastic modulus (GPa) | Tensile strength (MPa) |
|----------|----------------|---------------|-----------------|------------------|-----------------|----------------------|-----------------------|
| value    | Straight       | 6             | 0.019           | 631              | 0.91            | 3.5                  | 350                   |

2.2. Mixes composition of CMs

Fresh CMs were formed through the usage of 0.35 water/binder (W/B) portion and 3:1 sand/binder weight portion (S/B) as well as the same W/B portion was used in cement paste preparation [33]. Paste and mortars were formed through the usage of 30%, 20%, 10% and 0% metakaolin (first group) while the second group composed of a constant metakaolin percentage (20wt%) accompanied by various percentage of nanosilica (NS) as a replacement for cement 6%, 4%, 2% and 0% in weight. Third group composed of the usage of PPF amount in 0 and 0.2% of the binder, fourth group composed of a constant metakaolin percentage (0.2) accompanied by various metakaolin percentage as a replacement for cement 10%, 20%, and 30% MK in weight, and the fifth group composed of a constant metakaolin percentage (20wt%) and 0.2 PP, accompanied by various nanosilica percentage as a replacement for cement 0%, 2%, 4% and 6% NS in weight. In all groups, the SP quantity was 1.5 wt% of the binder cement. These mixtures are illustrated within tables 10 and 11.

Table 10. Mix composition of CMs.

| Mix component | Cement | Sand | Water | SP |
|----------------|--------|------|-------|----|
| Weight (g)     | 250    | 500  | 87.5  | 3.75 |

Table 11. Mix composition of the CMs with or without SF, MK and PP.*

| Group | Mix No. | Mix Notation | O.P.C | MK | NS | PP |
|-------|---------|--------------|-------|----|----|----|
| A     | 1       | M0           | 100   | 0  | 0  | 0  |
|       | 2       | Mk₁₀         | 90    | 10 | 0  | 0  |
| B     | 3       | MK₂₀        | 80    | 20 | 0  | 0  |
|       | 4       | MK₂₀        | 70    | 30 | 0  | 0  |
|       | 5       | MK₂₀NS₂     | 78    | 20 | 2  | 0  |
| C     | 6       | MK₂₀NS₄     | 76    | 20 | 4  | 0  |
|       | 7       | MK₂₀NS₆     | 72    | 20 | 6  | 0  |
| D     | 8       | PP 0.2      | 100   | 0  | 0  | 0.2 |
|       | 9       | PP₀₂MK₁₀    | 90    | 10 | 0  | 0.2 |
| E     | 10      | PP₀₂MK₂₀    | 80    | 20 | 0  | 0.2 |
|       | 11      | PP₀₂MK₃₀    | 70    | 30 | 0  | 0.2 |

*M0: control cement mortar; PP: polypropylene; MK: Metakaolin; NS: Nano-silica.
2.3. Production of specimens
The large surface area of nanoparticles affects their uniform distribution within the mix [20, 21] which
directly impacts the mortars mechanical characteristics. The production procedure of samples utilized
during this research was conducted following the ASTM C305 standard [22]. Nevertheless, the
necessity of conducting changes within the procedure of mixing was observed because of
nanoparticles presence. During the mixing, direct contact was avoided through the usage of gloves and
Masks. Firstly for 1 min, the MK and cement were dry blended within the mixer at 80 rpm (moderate)
velocity. After that these ingredients were blended for 90 s at 120 rpm (high) velocity accompanied by
the nanoparticles, the specified fibers quantity and 90% of the water. Then while the mixer was
running at 80 rpm (moderate) velocity, the addition of the sand was gradually conducted over a period
of 30 s. ultimately, the addition of the remaining water and superplasticizer were carried out and
stirred at 120 rpm (high) velocity for 30 s. Then the mix was left to rest for 90 s and after that the
blending was continued for one minute at 120 rpm (high) velocity. This procedure of mixing was
pursued to aid the fibers and the nanoparticles distribution within the mortar.

(50 x 50 x 50) mm cubes of casted fresh mortar were used for ultrasonic and compressive strength
tests and 40×40×160mm prismatic samples for test of flexural. The samples were condensed through
the usage of tamping rod to eliminate the air bubbles from the mortar. After that the samples were
cured and casted within water at 23 ± 3 °C then demoulded 24 hours till the specimens were tested.

2.4. Testing procedures
The test of Compressive strength was carried out following the ASTM-C109 standard [23] through the
usage of a hydraulic testing machine at 1350 N/s loading rate. The same specimens were dried for 3
hours at the laboratory environment then CHT-225A device was used to measure ultrasonic pulse
velocity (UPV) before carrying out the test of compressive. The test of three-point for loading flexural
(i.e. center-point) was conducted accompanied by 180 mm span at 44 N/s loading rate. The results of
compressive were detected at 3, 7, 28 and 90 curing days however results of flexural strength were
detected at 28 and 90 days. The three samples average value for the test was recorded.

3. Results and discussion
3.1. Compressive strength
The samples compressive strength in the absence and presence of polypropylene fiber at 3, 7, 28 and
90 days, respectively is shown in figures 3, 4 and 5. For both curing times, the compressive strength
incremented when raising the MK substitution from 10 to 20% after that the compressive strength
starts to drop at a substitution portion higher than 20%. Nevertheless, in spite of the decrement, the
mortar compressive strength including MK alone is still greater compared to the control samples. The
possible reason that MK is considered as a pozzolanic material that besides cement hydration
acceleration also interacts with (C−H) calcium hydroxide produced from the Portland cement
hydration. Subsequently, the concrete microstructure and hydration products chemistry are changed by
pozzolanic reactions through the consumption of discharged calcium hydroxide (C−H) besides the
production of extra calcium silicate hydrate (C−S−H) which produce in a decremented porosity and
incremented strength. Thus, stronger bond between the fine aggregates and the cement paste is arisen
from the raise within compressive strength within MK20 and MK10. The cement matrix homogeneity
and density is enhanced due to the cause that MK is finer compared to OPC through the restriction of
growth of C−H crystal and the reservation of better C−S−H distribution that causes the existent pores
blockage and thus, alter the structure of pore. MK is characterized by a fine divided material which is
considered as a thermal activated aluminosilicate material that forms a reaction within the moisture
existence and with slaked lime at ambient temperature to form a strong slow-hardening cement which
is formed through clay calcinations to obtain kaolin at temperature ranged from 700 to 850 °C without
production of CO₂ [24, 34].
The compressive strength reduction from MK20 to MK30 could be possibly explained by twofold. Firstly, the development of an inadequate hydration is observed due to the inadequate water quantity because of the extreme need of MK for water. Secondly, The non existence of sufficient C—H to form a reaction at a high content rate with the MK, for instance, within the usage of MK 30, some of the MK behaved as a filler only and did not participate in the reaction as shown within the photograph of SEM in figures 6(a). The high C—H concentration which is accessible for pozzolanic reaction is formed due to the pozzolanic reaction high amount within cement pastes accompanied by a low substitution amount with [25]. Table 5 is considered as illustration for chemical composition where the Al and Si emitted from the MK are attributed to the huge purities of aluminosilicate of this mineral.
Besides, the creation of convenient conditions for the composition of certain C—A—S—H quantities such as binding gels phases, in spite of the low MK proportions as well as fostering aluminosilicate portion akin to the filler impact due to the presence of the MK particles. According to other studies, the strength was enhanced and reached the highest level at 20% of MK substitution, however, the reduction in compressive strength was observed at MK >30% [26, 27].

The compressive strength was enhanced the usage of NS content till 4% accompanied by a constant value of MK 20% as shown in figure 3; nevertheless, the strength decreased as NS content increased. This could be explained as illustrated in Fig.5-b, for admixture includes 6% NS. The reaction between the nanoparticles and calcium hydroxide within lime solution is considered as the reason for the increment of compressive strength due to the production of additional C—S—H gel [28]. Ghafari et al. [29] reported that in order to accomplish the highest compressive strength, the optimal cement substitution quantity by nanosilica was 4wt% that coincides with the current study. However, Massana et al. [30] reported the nanosilica addition till 7.5wt% is recognized to increment the compressive strength.

The compressive strength raised consistently by adding polypropylene fiber (PP) accompanied by similar trend for 90, 28, 7 and 3 days as shown in figure 4. The highest strength was figured out within
PP0.2 MK20 NS4 accompanied by a 40% raise compared to the control admixture. The negative impact of the addition of cement containing high NS could be compensated though adding PP fiber. The reason for the compressive strength increment as the following: the ability of fibers to postpone the cracks growth rate, alter the cracks direction, minimize stress concentration extent at cracks tip, and control the cracks extension [31]. This coincides with Hsie et al. outcomes [19], which stated that the usage of polypropylene hybrid fiber enhanced the samples compressive strength. Mortar specimen SEM micrograph accompanied by 0.2% PP and 20% MK is illustrated in figure 5. A compact hydration products formation and raised C-S-H crystals content are illustrated in 0.2PPMK20NS4 micrograph. PPF are recognized to be able for holding the cracks propagation and bridging across the cracks and voids in the concrete.

3.2. Flexural strength
The mortar samples flexural strength in the absence and presence of polypropylene fiber (PP) at 90 and 28 days was illustrated in figures 7, 8 and 9. In accordance with the results, the flexural strength values improved slightly within admixtures including MK compared to the control mortar. As the addition of NS and substitution content of MK raised, the admixture flexural strength reduced and achieved a minimum within MK20NS6 that reduced by around 18.7% compared to the control samples at both 90 and 28 days. Generally, the flexural strength was improved through the substitution with constant 20% MK accompanied by various NS portion weather at 90 or 28 days. The MK impact as partial substitution for cement within concrete was investigated by Murali and Sruthee [32]. The flexural strength was enhanced within concrete by 9.3% through the usage of MK at the optimum ratio which approached 7.5%. The flexural strength was increased significantly that was illustrated in Fig. 9 which demonstrated the PP fibers importance within improving the mortars flexural strength. A growth of 24% in the flexural strength was recorded which was considered the highest compared to the control specimens at 90 and 28 days. The increment within flexural strength was caused by the fibers bridging impact due to the appropriate mechanical bonding between fibers and paste of the cement. Thus, within the fiber-reinforced mortars fracture process, the failure planes and the cracks of fibers bridging within the matrix could afford certain impedance for the crack propagation prior being stressed to or pulled out the rupture point.

![Figure 7: Flexural strength of specimens with replacement different % MK at 3, 7, 28 and 90 days](image)

3.3. Ultrasonic pulse velocity
Two main functions of ultrasonic Pulse Velocity (UPV) were determined; Firstly establishing a relationship within nondestructive way between mortar internal structure and water absorption, Secondly, providing information about the samples internal structure. To carry out the UPV test, 50 × 50 × 50mm samples were utilized within this research. This technique depends on the assessment of the pulse propagation velocity for vibration energy that crossed a medium of concrete. According to the results, combining 20, 10% MK, without PP or NS, enhanced the UPV by 22% and 13.5%,
respectively, compared to the control sample, while the 15% MK combination reduced the pulse velocity by 2% compared to MK10 (figure 10) which coincidence with Khatib et al. results[25]. The highest level of UPV achieved at 28 curing days for all mortar admixtures at 20% MK while the UPV declined for values of MK higher than 20%. The hydrated phases amount such as calcium silicate hydrates were considered from the factors that impact the enhancement of cement mechanical properties significantly. The pozzolanic materials usage such as MK could chip within the hydrated phase composition. The occurrence of pozzolanic reactions was recognized within mortars that included main products of MK which own C─A─S─H, C─S─H, and a less extent, C─A─H. Combining 4% of NS content could enhance the UPV particularly. According to the results of all the samples, the UPV was reduced for NS content higher than 4. Thus, 4% is considered an optimum ratio for NS substitution. The enhancement in the properties of the specimens combined with NS could be due to the NS physical and chemical effects. For the physical effect that could be recognized as filler impact, the solid materials packing was encouraged by NS particles through stuffing the gaps between the grains of cement. The chemical effect depends on reactions of pozzolanic between the calcium hydroxide (C─H) formed by the hydration of cement to produce calcium-silicate-hydrates (C─S─H) and NS amorphous silica. Besides, a huge number of nucleation sites were generated from the addition of small particles for the hydration products precipitation [35]. Thus, the reaction would be accelerated which lead to the formation of smaller C─H crystals.

Figure 8:- Flexural strength of specimens with constant 20% MK and with different % of NS at 3, 7, 28, and 90 days.

Figure 9:- Flexural strength of specimens with polypropylene at 3, 7, 28 and 90 days.

The Transformation probability for the continuous pores into discontinuous ones and the reduction in the large pores numbers from the causes of NS usage. Therefore, all these mechanisms produce the paste microstructure denser and homogeneous. A micrograph of the admixture including substitution
(NS and MK) was illustrated in figure 5 (SEM) that includes reduced C─H crystals content and compact hydration product composition that causes a reduction for the total porosity amount till the minimum compared to the control sample mortar. Nevertheless, the UPV was reduced through the addition of 6% NS. Generally, even though UPV decreased with raising NS by a value higher than 4% but it was still greater than the control sample UPV. Due to the low value of NS specific gravity compared to cement, raising the content of NS provides an increase to a lower density of mortar and thus a lower UPV.

As illustrated in figure 10 for polypropylene (PP), mixtures accompanied by 4% NS illustrated the largest value of UPV compared to the other mortar samples. The total velocity reduced as the content of NS raises in the PP contained samples that illustrate a decline within the propagation pulse velocity of vibration energy that crossed the mortar. Nevertheless, UPV was specified by a high value in all mixtures compared to the control admixture.

![Figure 10. Ultrasonic pulse velocity of the specimens with and without polypropylene at 28 days.](image)

4. Conclusions
An improvement in the compressive strength has been observed at 3, 7, 28 and 90 days due to the usage of a mixture of 20% MK and 4% NS. The compressive strength has been enhanced slightly when 0.2% PP fibers has been added. For instance, PP0.2 MK20 NS4 sample enhanced the compressive strength by 19.35% compared to the control sample. Generally, a non considerable impact effect on the flexural strength for partial substitution through the usage of MK and addition NS was observed. The highest flexural strength was acquired at MK20 within without PP samples. A substantial enhancement within the flexural strength of specimens was detected due to the PP integration into mortars as an additive. For instance, PP0.2 MK20 NS4 enhanced the flexural strength by 24%, compared to the control sample mortar. Particularly, similar trend within flexural strength could be detected at both 90 and 28 days. Regards to UPV, the replacement of NS up to 4% and 20% MK enhanced the velocity of ultrasonic pulse. Also PP addition is recognized to have a similar trend. Besides, an increment velocity was noticed due to the addition of PP fibers where a significant rate was observed for 20% NS and MK specimens. The 4% is considered as an optimal content for both 20% NS and MK in samples with or without PP.

References
[1] Morsy M S, Alsayed S H and Aqel M 2011 Construct. Build. Mater. 25 145
[2] Collepardi S, Borsoi A, Olagot J O, Troli R, Collepardi M and Curzio A Q Proceedings of the International Conference held at the University of Dundee, Scotland, UK on 7 July 2005, Thomas Telford Publishing, pp. 55-66.
[3] Marchon D, Kawashima S, Bessaies-Bey H, Mantellato S and Ng S 2018 Cem.Conc. Res. 112 96
[4] Gaitero J J, Campillo I and Guerrero A 2008 Cem.Conc. Res. 38 1112
[5] Qing Y, Zenan Z, Deyu K and Rongshen C 2007 Construct. Build. Mater. 21 539
[6] Jalal M, Pouladkhan A, Harandi O F and Jafari D 2015. Construct. Build. Mater. 94 90
[7] Li H, Zhang M H and Ou J 2006 Wear 260 1 262
[8] Jo B W, Kim C H, Tae G H and Park J B 2007 Construct. Build. Mater. 21 1351
[9] Li G. 2004. Cem.Conc. Res. 53 68
[10] Klimesch D S and Ray A 1998 Adv. Cem. Bas. Mat. 7 109
[11] Abdel-Gawwad H A, El-Enein S A, Heikal M, Abd El-Aleem S, Amer A A and El-Kattan I M 2018 Construct. Build Mater. 176 676
[12] Siddique R and Klaus J 2009 App.Ci.Sci. 43 392
[13] Khatib J M and Hibbert J J 2005 Construct. Build. Mater. 19 460
[14] Kim H, Lee S and Moon H 2007 Construct. Build. Mater. 21 1229
[15] Lindgård J, Thomas M D, Sellevold E J, Pedersen B, Andić-Çakır Ö, Justnes H and Ronning T F 2013 Cem. Conc. Res. 53 68
[16] Abdel-Gawwad HA, Mohammed MS and Alomayri T 2019 Constr. Build.Mater. 228 116827
[17] Akcaya B and Tasdemir M A 2018 Construct. Build Mater. 185 436
[18] Madandoust R and Mousavi S Y 2012 Constr. Build. Mater. 35 752
[19] Hsie M, Tu C H and Song P S 2008 Mater.Sci. Eng. A 494 153
[20] Tawfik T A, Abd EL-Aziz M A, Abd El-Aleem S and Serag Faried A, 2018 J. Chi.Adv.Mats. Soc. 6 409
[21] Sobolev K, 2006 NSF Workshop on Nanomodification of Cementitious Materials, Portland Cement Concrete and Asphalt Concrete.
[22] ASTM C305 2011 (Annual Book of ASTM Standards, ASTM) Philadelphia PA
[23] ASTM 2007 (ASTM C109-99) West Conshohocken PA
[24] Zheng Z and Feldman D 1995 Pro. Poly. Sci. 20 185
[25] Rashad A M 2015 Mater. Des. 52 143
[26] Khatib J M, Negim E M and Gjonbalaj E 2012 Wor. J. Chem. 7 7
[27] Vejmelkova E, Pavlikova M, Keppert M, Keršner Z, Rovnaniková P, Ondráček M and Černý R 2010 Construct. Build Mater. 24 1404
[28] Weng T L, Lin W T and Cheng A 2013 Sci. World. J. 2013 606524
[29] Ghafari E, Costa H, Júlio E, Portugal A and Durães L 2014 Mater. Des. 59 1
[30] Massana J, Reyes E, Bernal J, León N and Sánchez-Espinosa E 2018 Construct. Build Mater. 165 93
[31] Mohseni E, Yazdi M A, Miyandehi B M, Zadshir M and Ranjbar M M, 2017 J. Mater. Civ. Eng. 29 04017025
[32] Shivram B and Nagesh P 2007 Cem. Compos. 21 38
[33] Abo-EL-Enein S A, Abdel-Gawwad H A, Hodhod OA and El-Kattan I M 2016 J. Am. Sci. 12 51
[34] Abdel-Gawwad H A, Hassan H S, Vásquez-Garcia, S R, Israde-Alcántara, I, Ding Y C, Martínez-Cinco M A, Abd El-Aleem S, Khater H M, Tawfik T A and El-Kattan I M 2020 J. Clean. Prod. 252 119875.
[35] El-Kattan I M, Abdelzaher M A and Farghali A A 2020 J. Mater. Res. Tech. https://doi.org/10.1016/j.jmrt.2020.05.087