Effect of Polypropylene Fibers on Properties of Mortar Containing Crushed Brick as Aggregate

*** Shakir A. Salih & Maha E. AL-Azaawee**

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Abstract:

More recently there has been a great attention towards converting waste materials by- products into useful materials as aggregate in concrete industry. It is thus aimed in this study to investigate the possibility of using waste brick as suitable materials and alternative to the natural aggregate in the production of lightweight mortar.

The essential objective of this work is to study the mechanical properties of lightweight mortar containing different percentages of polypropylene fiber with high range water reducing agent. The effective synergy of this admixture on the properties of mortars is also investigated. Compressive strength, splitting tensile strength, thermal conductivity and drying shrinkage tests were conducted on reference and polypropylene fiber reinforced mortar specimens at various ages of curing (7, 14, 28, 60 and 90 days) respectively.

The results show a significant increasing in splitting tensile strength with the increment of fibers content. Although, a considerable reduction in workability is recorded as increasing the fiber content. Which is controlled by using high range water reducing admixture. All mixes show acceptable values for thermal insulation with regards to ACI 213-87 thermal insulation recommendations.

Keyword: Lightweight Mortar, Crushed Brick Aggregate, Polypropylene Fiber.

تاثير الياف البولي بروبلين على خواص المونه الحاوية على ركام الطابوق المكسر

الخلاصة

لوحظ مؤخراً وجود أهتمام كبيرنحو تحويل مخلفات المواد الى مواد مفيدة كركام في الصناعة الخرسانية. لهذا تهدف هذه الدراسة الى البحث عن أمكانية أستخدام الطابوق المكسر كمواد مناسبة و بديلة للركام الطبيعي في أنتاج الملاط الخفيف الوزن.

أن الغرض الرئيسي من هذا البحث هو التعرف على الخصائص الميكانيكية للملاط المسلح بنسب مختلفة من ألياف البولي بروبيلين مع المضاف المقلل للماء بدرجة عالية' أضافة الى دراسة تأثير هذا المضاف على جميع الخواص. تم اجراء فحوصات مقاومة الانضغاط ' مقاومة الشد (غير المباشر) 'الموصلية الحرارية و انكماش الجفاف لخلطات (الملاط) المرجعية والحاوية على ألياف البولي بروبيلين خلال فترات مختلفة من معالجة الخرسانة (14,7, 28, 60, و 90 يوم).

بينت النتائج زيادة ملحوظة في مقاومة شد الانفلاق مع زيادة محتوى الالياف على الرغم من تسجيل انخفاض مناظر فبي قابلية التشغيل كلما زاد محتوى الالياف. وقد تمت السيطرة على هذا الانخفاض بقابلية التشغيل من خلال استخدام المضاف المقلل للماء بدرجة متفوقة. بينت جميع الخلطات قيم مقبولة للعزل الحراري بالمقارنة مع توصيات العزل الحراري الخاصة بمعهد الخرسانة الامريكي ACI 213-87 .

* Dept. of Building and Construction Engineering, Univ. of Tech.

1. Introduction:

Since the last few decades, there has been an increasing tendency worldwide to look out for materials that can be used as alternative for conventional materials. Therefore, researches have been carried out to study the use of crushed brick beneficially which must conform to the applicable engineering properties as the raw materials. Crushed brick may be used as a sub-base material for driveway, sidewalk, or roadway construction, base or fill in drainage projects, and for utilization as aggregate in new concrete manufacture which can be used for specific purposes such as: foundation concrete for light buildings, flooring, walkway and foundation beneath light traffic roads [1].

Recycling process is an economic phenomenon which represents the resumption of waste materials for obtaining alternative materials in construction industry. Recycled materials supply a large quantity of aggregate for concrete making, particularly in the areas which suffer from the decreasing of natural aggregate sources [2].

The recycled aggregate which is obtained from waste building materials decreases the demand for natural sources, provides cheaper and lighter than virgin aggregate, and reduces the disposal and transportation costs [3].

In Iraq clay brick is widespread as masonry units. A large number of these units are damaged in the production, placing, and handling due to its brittleness. Therefore the wastes of the produced clay brick units are disposed. Fortunately, the broken brick concrete is one of the solutions to overcome this problem. [4]

On the other side, the concrete made from these aggregates can be used to produce special type of concrete with the special property of reducing the dead weight of these sections, as well as ensuring the faster building rates, smaller support sections, corresponding reduction in the size of foundation, lower handling and transportation load with a consequent increase in productivity. Furthermore, the concrete of lightweight aggregate provides better heat-insulation capacity than concrete of normal density [1].

2. The Concept of Composites Material:

Various rigorous theoretical treatments of the behavioral mechanics of fiber-reinforced material have evolved over the years. The concrete is naturally a brittle material, and contains a large number of “Micro-cracks”, which are responsible for the weakness in tensile strength of concrete, and the opportunity for water and chemical invasion [5].

Therefore the inclusion of fibers as reinforcement is generally thought of as a remedy for the poor tensile strength of cement and concrete. The role of reinforcement, however, is not so much in the improvement of static strength as its control of cracking. The controlled cracking results in improved ductility, energy absorption, resistance to impact, shock, and thermal loading of the composite. On the other hand, the ability to control the size and

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amounts of cracks will also lead to enhanced durability as the composites can be designed to have the ability to reduce the amount of intrusion by aggressive environments [6, 7].

The real advantage of adding fibers is when fibers bridge these cracks and undergo pullout process such that the deformation can continue only with the further input of energy from the loading source. The objective function is the amount of energy absorbed to produce the cracks in the composite material and to open these cracks to certain widths, and the components of the energy absorption are due to the following phenomena [8, 9]:

- Debonding of the fibers from the matrix in the crack zone.
- Pulling-out of the fibers from the matrix.
- Passing of the fibers across the cracks.

Research Significance:

Clay brick units are very versatile medium for construction. Although, an energy-intensive process is required to manufacture them. In consequence of its brittleness nature, a large number of these units are probably damaged in production and handling. Therefore, the wastes of clay brick units are disposed. The utilizing of the damaged brick units was performed successfully as aggregate in concrete. In addition, this concrete has an acceptable load capacity, gives better thermal insulation and has less density than ordinary concrete.

But due to the brittleness of brick and thereby the concrete made with it, it is suggested to reinforce this concrete with fibers, thus enhancing its properties.

3. Experimental program:

3.1 Materials:

3.1.1 Cement:

Ordinary Portland cement manufactured in Lebanon (Turabt AL-Sabia) was used in this work. It was stored in a dry place (large air-tight plastic containers) to avoid exposure to atmospheric conditions like humidity.

The percentage oxide composition and physical properties of the cement indicate that the adopted cement conforms to the Iraqi Specification No.5/1984 [10].

3.1.2 Broken Brick Aggregate:

The broken brick aggregate was used as fine aggregate, and the required quantity of crushed brick was brought from different locations. After that the large pieces were crushed into smaller sizes manually by means of hammer in order to facilitate the insertion of broken brick through the feed opening of the crusher machine. The (Jaw crusher) was set up to give a finished product about (12.5 mm) maximum aggregate size.

The aggregates taken from the crusher were brought and put into (Loss Anglos mining) for about (10 min).

After that the aggregate taken from the mining was screened on a standard sieve complying with **ASTM C136-01** specification [11]. An electrical sieve shaker performed the screening for about 5 minutes. Retained materials on each sieve were set apart in large plastic vessels.

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The individual size fraction for each batch was recombined in proper proportions to produce the desired grading, then the required quantity of the brick aggregate for each batch was washed with water in order to remove the dust associated with crushing process because high content of dust leads to segregation and causes crazing of exposed concrete [12].

Additionally the aggregates were submerged in water for about (24 hr), and they were dripped off and spread inside the laboratory in order to bring the aggregate particles to saturated surface dry (S.S.D) condition, as **ACI committee 211-2-81** [13] recommends. The grading of fine brick aggregate that was used throughout this work is shown in Table (1), and it is within the limits of **ASTM C330-02** [14].

Several physical and chemical properties were determined for fine brick aggregate, some of these properties would be used as required data for mix proportioning purposes, such as unit weight and absorption. Table (2) lists these properties and their corresponding proper specifications.

3.1.3 Superplasticizer:

The superplasticizer based on modified polycarboxylic ether was used on this research which is known commercially as **(GLENIUM 51).**

It differs from conventional superplasticizers in that it was based on a unique carboxylic ether polymer with long lateral chains, which improves cement dispersion. At the start of the mixing process electrostatic dispersion occurred but the presence of the lateral chains, linked to the polymer backbone, generates a steric hindrance. This steric hindrance stabilizes the cement particles capacity to separate and disperses. This mechanism provided flowable concrete with greatly reduced water demand. Table (3) indicates the technical description of the aqueous solution of superplasticizer used throughout this investigation which was issued by ASTM C494-C494/04 [15]. **(GLENUIUM 51)** is free from chlorides and complies with ASTM C494-C494/04 types A and F.

3.1.4 Polypropylene Fiber (PPF):

High performance short (12 mm) polypropylene fiber was used in this investigation. This fiber shows a micro reinforcement manufactured from (100%) polypropylene. It was brought from Fosroc Company for Construction Chemicals. Polypropylene fiber complied with requirements of **ASTM C1116-1997, TypeIII** [16]. It was stored under cover away from heat sources. Table (4) shows the physical and technical properties of polypropylene fiber.

3.2 Mixes:

The fine brick aggregate was used as 100% replacement of natural sand to produce lightweight mortar with (1:2.5) (cement: fine aggregate) ratio by weight, the cement content was (550 kg/m^3) and the (w/c) ratio to maintain a flow of 100±10 mm was (0.49).

Five mortar mixes were used which were reinforced with different volume fractions (0.5%, 1% and 1.5%) of polypropylene fibers. The

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details of all mortar mixes used throughout this investigation are shown in Table (5).

3.3 Casting and Compaction:

According to **ASTM C192-88** [17]**,** after mixing process, the mix was immediately poured into moulds by means of a scoop. Casting of the samples was carried out in two layers; each layer was compacted by using a vibrating table. The complete compaction was determined by appearance of a film of cement mortar on the top and the air void was no longer appearing. Only thermal conductivity specimens were cast in one layer and were compacted. After compaction, the top surfaces of specimens were trowelled level for obtaining smooth surface. The whole work is carried out at winter season.

3.4 Curing:

After casting, all specimens were kept under nylon sheets inside the laboratory for (24±2) hours to assure a humid air around the specimens and to prevent fast evaporation of water from the specimens, and then they were demoulded and cured until they were tested. All specimens prepared for compressive, splitting tensile, and thermal conductivity, were stored in tap water tanks until testing age. While specimens prepared for length change test were stored in tap water tanks until the age of 7 days then they were removed and stored in a dry place inside the laboratory until the age of 3 months.

3.5 Tests:

3.5.1 Flow Table Test for Consistency of Mortar Mixes:

The amount of water required for standard consistency of plain mortar or fiber reinforced mortar was determined by the flow test.

Flow table was prepared according to **ASTM C1437-01**[17] for use in tests of hydraulic cement. The amount of mixing water was sufficient to produce a flow of (100±10) mm expressed as a percentage of the original diameter of the flow mould. The required amount of water for standard consistency of mortar was expressed in terms of (w/c) ratio.

4.5.2 Compressive Strength Test:

Compressive strength tests were conducted on a (100) mm mortar cubes according to the **B.S. 1881 Part116: 1983** [19] by using 2000 kN capacity, ELE Digital Electric testing machine. The loading rate used in the test was 0.3 MPa/sec. The test was conducted at ages of (7, 28, 60 and 90) days and three specimens were tested at each age.

4.5.3 Splitting Tensile Strength Test:

The splitting tensile strength test was performed according to **ASTM C-496** [20]**.** Cylinders of (100×200) mm were used and the load is applied continuously up to failure using a standard testing ELE-machine of capacity 2000 kN. The test was conducted at ages of (7, 28, 60 and 90) days. The average of three specimens at each age was taken.

4.5.4 Length Change Test:

To determine the length change, (25×25×285) mm prisms were tested in accordance with **ASTM C157-89** [21].Two gage studs were fixed on two sides (parallel to the center axis) of each specimen immediately after

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demoulding, they were placed in water for 7 days. After this the specimens were removed from water and immediately the initial dial gauge readings were taken. Then the specimens were stored in air, inside the laboratory. The length change tests were taken at ages (7, 14, 28, 60 and 90) days after curing. The length change of specimens was measured by means of a length compresso-meter satisfying the requirement of **ASTM C490-00a** [22].The specimen was rotated slowly in the measuring device, while measurement of length was being made. The minimum reading of the dial gauge was recorded, if the rotation caused a change in the dial gauge. The accuracy of the dial gage of the measuring device is (0.002) mm [22].The average reading value of four readings from two prisms was adopted for each mix.

4.5.5 Thermal Conductivity Test:

The thermal conductivity test was carried out according to **B.S.874**. [23]. A special mould was prepared to produce the required specimen with diameter of (40 mm) and (10 mm) thickness; four specimens were produced for each mix and tested at (28 days). **Lee's disk** method was used for determining the thermal conductivity (K).The test sample was placed between two conductive brass discs (A and B), heating coil was connected to the battery, the thermal conductivity test was conducted by Applied Science Department Laboratories in the University of Technology. Thermal energy could be calculated, which passed through the heating coil at equilibrium from getting the thickness of discs (A, B, C, and S) and the temperature of (T_A, T_B, and T_C) from the relation:

$$IV=\pi r^2 e\ (T_A+T_B) + 2re\ [d_A T_A + (d_S/2)(T_A+T_B) + d_B T_B + d_C T_C] \quad \ldots\ldots\ (2)$$

where:

I: current, amperes.

V: voltage.

r: radius of the disk,(mm)

e: required heat to pass through unit area of the disk material per second**.**

Therefore, (e) can be calculated from the above equation, which represents the thermal energy. To calculate (K) the following equation is used:

$$K\ [(T_B-T_A)/d_S] = e\ [TA + (2/r)(d_A+d_S/4)\ T_A + dsT_B/2r] \quad \ldots\ (3)$$

where:

T: disk temperature, (ºC).

d: disk thickness, (mm).

5. Results and Discussions:

5.1 Workability:

The results of workability tests for mortar mixes are shown in Table (5). The data results indicate that the addition of fine brick as full replacement of natural sand (100%) by volume causes an increase in the (w/c) required. This is due to higher porosity and roughness of crushed brick aggregate. This increase in (w/c) is due to the higher ability of fine brick aggregate to absorb water. Also more water is required for motility to overcome the inter-particle friction between particles.

The effect of superplasticizer on reducing the (w/c) ratio while maintaining equal workability as with reference mixture was investigated. At the optimum dosage of superplasticizer, the (w/c) ratio is

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adjusted for all mortar mixes to fulfill the workability requirement.

The addition of polypropylene fibers caused a noticeable reduction in workability with increasing the fiber volume fraction. The flow test decreases with increasing the volume fraction of polypropylene fiber; however a suitable amount of water is added to improve the workability of mortar mixes. For example the w/c for M-0.5P, M-1P and M-1.5P mixes were (0.45, 0.48 and 0.51) respectively.

5.2 Compressive strength:

The compressive strength test results at various curing ages for all types of mortar are presented in Table (6). Results show that the compressive strength decreases when adding the fine brick aggregate as full replacement of natural sand. The main reason for this decrease in compressive strength is that the replacement of fine brick aggregate consists of harsh and porous particles, which need a greater amount of water to saturate. As well as the lower modulus of elasticity for brick compared with sand.

There was a considerable improvement in compressive strength of (HRWRA) mixes relative to their control mix without (HRWRA) as shown in Table (6) and Fig. (1). At 90 days the percentages of increase in compressive strength measured relative to reference mix is (27.23%) for M-H mix respectively. This behavior is mainly due to the significant reduction in (w/c) ratio.

The other advantage that was attained by incorporation of (HRWRA) in mortar reinforced with polypropylene fiber was the dispersion of cement agglomerates into individual particles; thereby a greater rate of cement hydration can be achieved in the well disbersed system [24].

The addition of polypropylene fibers caused a reduction in the compressive strength as the percentage of polypropylene fiber increased more than (0.5%) by volume fraction. For example, at 90 days the compressive strength for M-0.5P, M-1P and M-1.5P mixes were (46.81, 40.94 and 36.80) MPa respectively. This reduction refers to the low modulus of elasticity for polypropylene fiber, thus causing (de-bonding) between the fiber and matrix and the propagation of micro cracks because of the poor physicochemical bonding strength with cement paste. Therefore the failure occurred with lower load when compared with reference mixes.

5.3 Splitting Tensile Strength:

The developments of splitting tensile strength with age for fine brick aggregate mortar with and without polypropylene fiber are also shown in Table (7). It is found that the splitting tensile strength is decreased when adding fine brick aggregate. At 90 days the splitting tensile strengths for M mix are (2.33) MPa, as shown in Fig. (2).

Data also show that the splitting tensile strength is improved when adding (HRWRA) to the mortar mixes. The incorporation of (HRWRA) in fine brick aggregate mortar leads to higher tensile strength compared to their corresponding reference mix at all ages, as shown Fig. (2). For example at 90-day age the

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percentage increase in splitting tensile strength for M-H mixes as compared with reference mix (without admixture) is (44.64%). This is ascribed to the significant reduction in capillary porosity caused by reducing water content of the mix. Besides, the good dispersion of cement particles gives a greater statistical chance for intermeshing of the hydration products with fine aggregate surface.

The splitting tensile strength for polypropylene fiber reinforced mortar with different volume fraction (0.5%, 1% and 1.5%) is considerably higher than that of the corresponding reference mortar mixes containing no fiber for all ages of curing. The percentage increases in splitting tensile strength at 90 days of age of curing for M-0.5P, M-1P and M-1.5P mixes measured relative to HRWRA mix without fibers are (13.35%, 26.41% and 32.05%) respectively. This is due to the action of fibers as crack arrestor

5.4 Length Change:

Results of length change for various types of mortar mixes up to 90 days are presented in Table (8) and Fig. (3). Results show that the shrinkage values increase with time especially after first 7days, but it can be noticed that no shrinkage is recorded before 7days due to immersion of all specimens in tap water which causes increase the length change (Expansion) during the time of submersion. After removal of the specimens from the water, all specimens started to shrink gradually. This is due to rapid loss of moisture from the surface of the specimens having high cement content. At later ages the increase in the shrinkage is reduced with time depending on the moisture movement of mortar.

The results show that the shrinkage values are very high as a result of presence of fine brick aggregate which had low modulus of elasticity. In addition the greater water demand for a given workability leads to greater shrinkage values. For example, the drying shrinkage value at 90 days is (0.0841%) for M mix.

(HRWRA) mortars without fibers show lower expansion and drying shrinkage compared with their reference mortars at all ages; see Fig. (3) and Table (8). For example, the percentages of decrease in drying shrinkage at 90 days measured relative to reference mortar mixes are (15.36%) for M-H mix. This reduction is due to lower w/c ratios for (HRWRA) mortar compared to reference mortar.

On the other hand, incorporating polypropylene fibers affects the drying shrinkage of mortars. Also, the higher polypropylene fiber content leads to considerably lower shrinkage values as presented in Fig. (3) at various ages. The inclusion of (PPF) reduces shrinkage compared with reference mix. At 90 days the drying shrinkage values are (0.0570%, 0.0540% and 0.0475%) for M-0.5P, M-1P and M-1.5P mixes respectively. This is attributed to the ability of polypropylene fiber to minimize cracks density, individual crack length and width as compared to control batch without fibers and hence the

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shrinkage is restrained by addition of fibers.

5.5 Thermal Conductivity:

The test results for the thermal conductivity values of all mortar mixes are listed in Table (9), which illustrates that using fine brick aggregate improve the thermal insulation property, as shown in Fig. (4). Fig.(4) shows that the conductivity values decrease with the increase of fibers content. For example, the thermal conductivity for M mix at 28 days is (1.0015) W/m.K. This is attributed to the cellular and porous nature of fine brick aggregate, which resists the heat flow through the mortar and affects the conductivity of the produced material.

Also Table (9) demonstrates that (HRWRA) mortar mix has higher thermal conductivity than control mix. For example, the thermal conductivity for M-H mixes is (1.0113) W/m.K. This is due to the higher density of (HRWRA) mortar mix and consequently lower air voids.

In addition it is found that the addition of polypropylene fiber causes a noticeable reduction in the values of thermal conductivity. At 28 days the percentages decrease in thermal conductivity for M-0.5P, M-1P and M-1.5P mixes measured relative to M mix are (26.67%, 48.64% and 83.42%) respectively. This reduction can be attributed to the good thermal stability and lightweight of polypropylene fiber themselves which increase the insulation property of the system and decrease the density of final mixes especially when increasing the volume fraction of polypropylene fiber.

Conclusions:

This study has investigated the behavior of fiber reinforced lightweight fine brick aggregate mortar to improve the mechanical properties; chemical admixture was used with polypropylene fiber. On the basis of the results of this work, the following conclusions may be deducted:

1. Using of fine brick aggregate (100%) as full replacement by volume of natural sand leads to increase the mortar demand for water.
2. The use of polypropylene fiber affects the workability of fiber reinforced mortars. Polypropylene fibers of more than 1% produce harsh mixes significantly. But the use of superplasticizer improves the workability of mixes containing high volume fraction of fiber.
3. The use of (HRWRA) **(4.5%)** by weight of cement as a high range water reducing admixture, improves the mechanical properties of the matrix, compressive strength by about (21.40%), splitting tensile strength by about (30.86%), at 90 days respectively.
4. All mortar mixes show significant reduction in compressive strength with fine brick aggregate content as full replacement of sand by volume by about (9.26% to 24.15%) at age of 28 days. The use of polypropylene fiber decreases the compressive strength when fiber volume fraction exceeds (0.5%) by about (10.42%) and (24.18%) for (1 and 1.5%) volume

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fraction of polypropylene fiber respectively.

5. Mixes containing superplasticizer show clear improvement in splitting tensile strength compared with control mixes at all ages. At 28 days the splitting tensile strength is about (3.19) MPa Conversely, the incorporation of polypropylene fiber increases the tensile strength of all mixes significantly. Furthermore, the increase in volume fraction of fibers leads to an increase in the tensile strength of mortars by about (7.21%), (16.93%), (21.32%) at 28 days for polypropylene fiber volume fraction of (0.5%, 1% and 1.5%) respectively.
6. Generally drying shrinkage of all specimens increases with age up to 90 days. Drying shrinkage of mixes containing fine brick aggregate is high. Polypropylene fiber reinforced mortars exhibit lower shrinkage than corresponding reference mortars (without fibers) ranging between (0.0570% to 0.0475%) for fine brick aggregate mixes with (0.5, 1, 1.5%) volume fraction of polypropylene fiber. This reduction in drying shrinkage increases with increasing the percentage of volume fraction of fiber.
7. The thermal insulation values of mortars are within the ACI 213-87 thermal insulation recommendations. But HRWRA mortars show higher conductivity than reference mixes. The incorporation of polypropylene fiber improves the thermal insulation of all mixes significantly. Furthermore, increasing fiber volume fraction leads to a decrease in the thermal conductivity of all mixes. The range of K-value of the brick aggregate mortar reinforced with different volume fraction of polypropylene fiber was between (0.5460 to 1.0015W/m.K).

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Table (1): Grading of Fine Crushed Brick Aggregate

Sieve size (mm)	Cumulative passing %	Cumulative passing % ASTM C330-03 Zone (1)
9.5	100	100
4.75	94	85-100
2.36	68	-
1.18	47	40-80
0.3	13	10-35
0.15	4.6	5-25

Table (2): Properties of Fine Crushed Brick aggregate

Property	Specification	Results
Specific gravity: Bulk oven dry basis Bulk SSD basis	ASTM C128	1.847 2.215
Absorption %	ASTM C128	20.64
Dry loose-unit weight ,kg/m³	ASTMC29/C29M/97	1076.68
Dry rodded-unit weight ,kg/m³	ASTMC29/C29M/97	1158
Aggregate crushing value, %	B.S. 812:part 110:1990	42.93
Aggregate impact value, %	B.S. 812:part 110:1990	44.3
Stain intensity Stain index	ASTM C641	No Stain 0

Table (3): The Technical description of high water reducing admixture (Typical properties)

Main Action	Concrete Superplasticizer
Appearance	Light Brown
Form	Viscous Liquid
Relative Density	1.1 gm/cm³ at 20° C
pH value	6.6
Recommended Dosage	(0.5-0.8) litter for 100 kg of cement
Chloride Content	None
Transport	Not classified as dangerous

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Labeling	**No hazard label required**

Table (4): Physical and Technical Properties of Polypropylene Fiber (PPF) used in this investigation

Composition	**100% Virgin polypropylene fiber**
Fiber length	**12mm**
Specific gravity	**0.91**
Melting point	**160°C**
Tensile strength	**(137-689) MPa**
Young's modulus	**(5500-7000) MPa**
Fiber thickness	**18-30 microns**
Elongation	**25-40 %**
Alkali content	**Nil**
Sulfate content	**Nil**
Chloride content	**Nil**

Table (5): The Workability results for all mortar mixes

Mix Designation	Fiber Volume Fraction %	(HRWRA) %by weight of cement	w/c Ratio	Water Reduction %	Flow (%) 100±10 mm
M	0	0	0.575	0	94
M -H	0	4.5	0.420	26.96	98
M-0.5P	0.5	4.5	0.450	21.74	95
M-1P	1	4.5	0.480	16.52	92
M-1.5P	1.5	4.5	0.510	11.29	88

Table (6): The Compressive Strength results for all mixes

Mix Designation	Compressive strength (MPa) at Ages of			
	7 days	28 days	60 days	90 days
M	19.75	27.26	31.68	35.92
M -H	31.50	38.17	42.39	45.70
M-0.5P	32.61	39.26	43.47	46.81
M-1P	26.78	33.45	37.68	40.94
M-1.5P	22.69	29.38	33.59	36.80

Table (7): The Splitting Tensile strength results for all mixes

Mix Designation	Splitting Tensile strength (MPa) at Ages of			
	7 days	28 days	60 days	90 days
M	2.01	2.13	2.24	2.33
M -H	2.77	3.19	3.28	3.37
M-0.5P	3.19	3.42	3.64	3.82

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M-1P	3.45	3.73	3.92	4.26
M-1.5P	3.68	3.87	4.16	4.45

Table (8): The length change results for all mixes

Mix Designation	Length Change % at Ages of				
	7 days	14 days	28 days	60 days	90 days
M	+0.0146	-0.0479	-0.0666	-0.0750	-0.0838
M -H	+0.0118	-0.0414	-0.0609	-0.0677	-0.0741
M-0.5P	+0.0096	-0.0348	-0.0489	-0.0531	-0.0570
M-1P	+0.0091	-0.0330	-0.0464	-0.0503	-0.0540
M-1.5P	+0.0080	-0.0292	-0.0408	-0.0443	-0.0475

Table (9): The thermal conductivity results for all mixes

Mix Designation	Thermal conductivity (W/m.K)
M	1.0015
M -H	1.0113
M-0.5P	0.7905
M-1P	0.6738
M-1.5P	0.5460

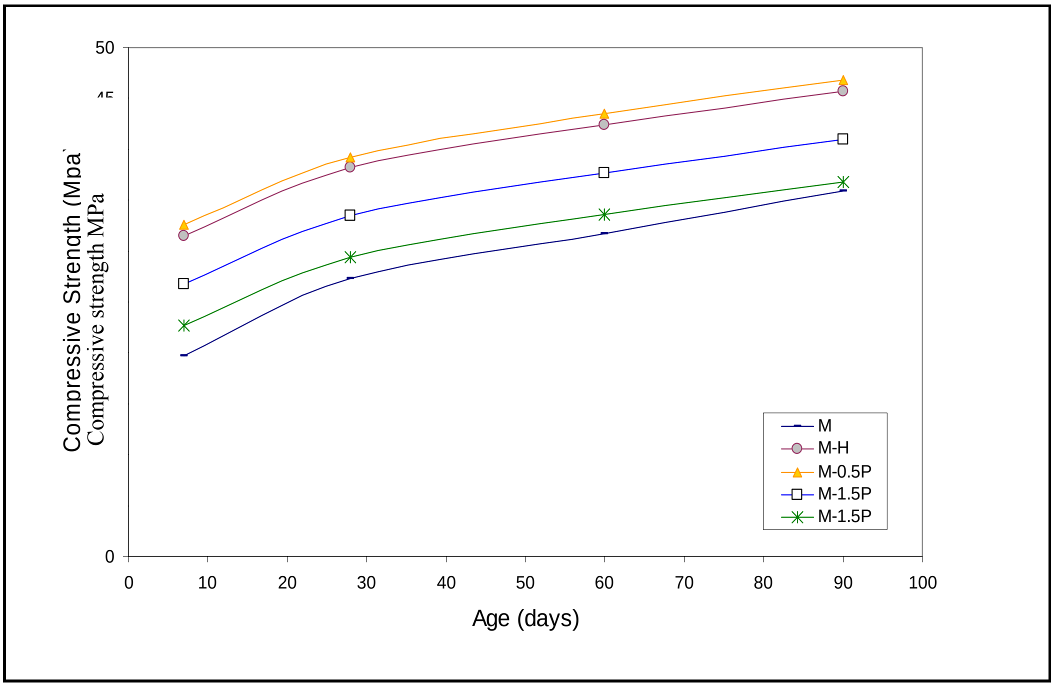

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Fig. (1): Effect of (100% fine brick), superplasticizer and different volume fractions of polypropylene fiber reinforced mortar on the compressive strength at various ages

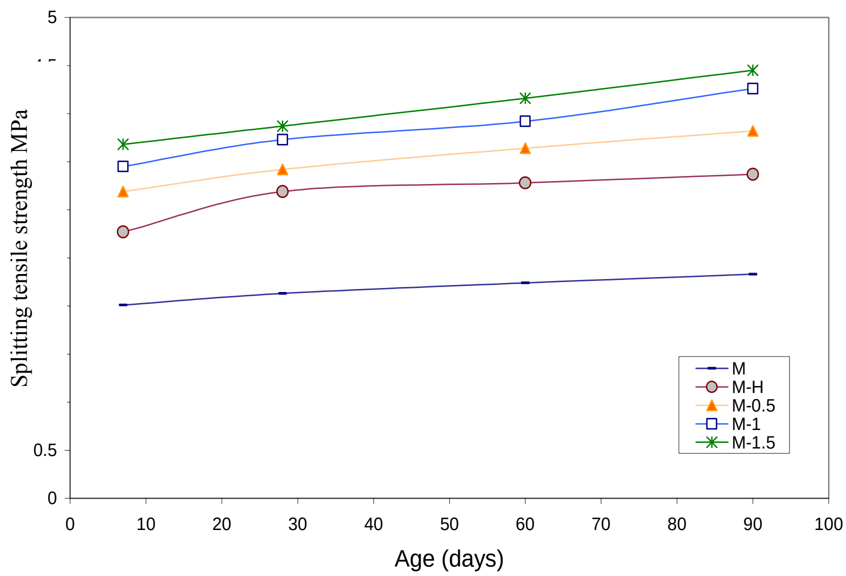

Fig. (2): Effect of (100% fine brick) and different volume fractions of polypropylene fiber reinforced mortar on the splitting tensile strength at various ages

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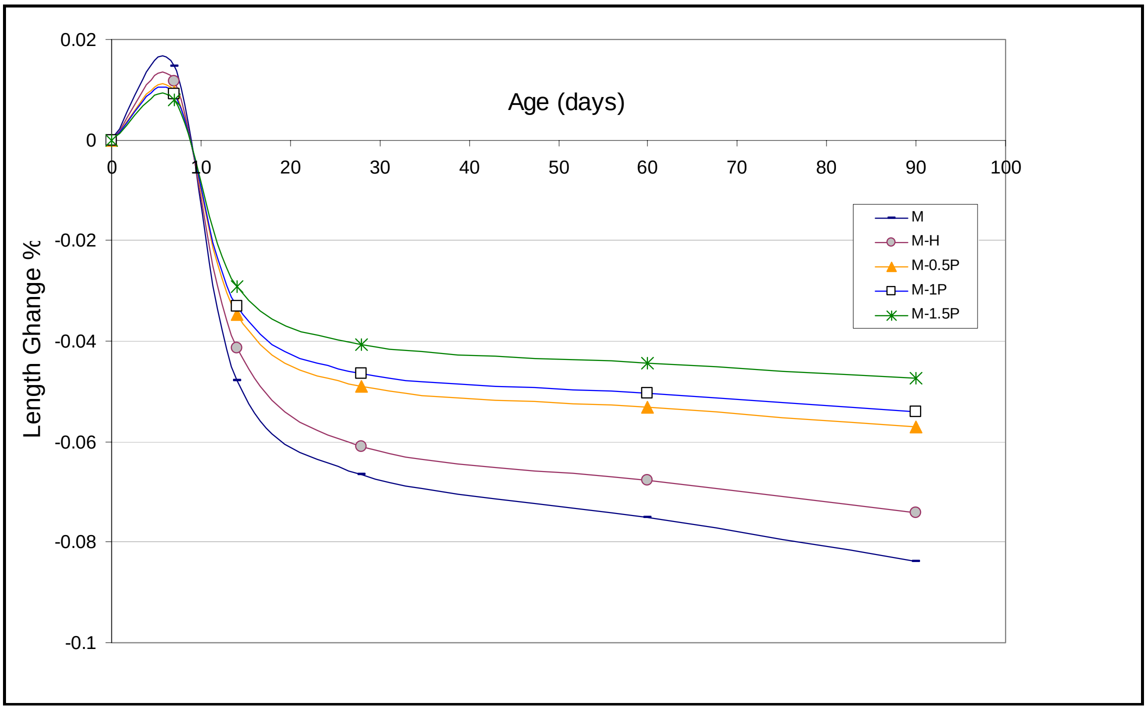

Fig (3): Effect of (100% fine brick) and different volume fractions of polypropylene fiber reinforced mortar on the Length Change at various ages

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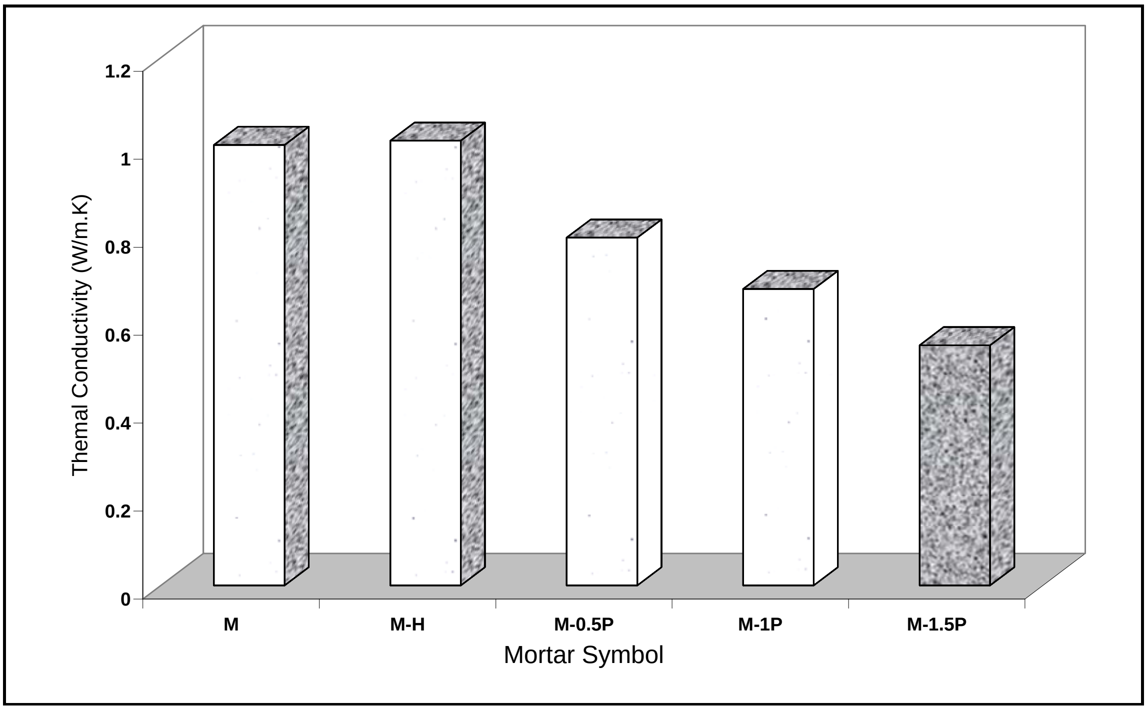

Fig (4): Thermal Conductivity for all Mortar Mixes

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