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Experimental investigation on pervious concrete with metakaolin.

Investigación experimental sobre hormigón permeable con metacaolín

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ABSTRACT

Pervious concrete is a type of light weight porous concrete with no fine or with small percentage of fine aggregate. It is generally used for flatwork applications, which allows water from precipitation and other sources to pass directly through, thereby reducing the runoff from a site and allowing ground water recharge. This study aims to experimentally investigate the mechanical and hydraulic properties of pervious concrete with different replacement levels of metakaolin. Pervious concrete for pavement applications having a porosity of 20-25% with cement-aggregate ratio of 1:4 and w/c ratio of 0.36 is established based on permeability, porosity and strength parameters. Metakaolin were incorporated in pervious concrete by replacing cement at 5%, 10% and 15% by weight of cement which helps in increasing the mechanical properties of pervious concrete. The strength parameters increased about 12.24%, 23.95%, 13.97% for compressive strength, split tensile strength and flexural strength respectively for 10% metakaolin replacement and hydraulic properties decreased as the percentage of metakaolin increased.

Keywords—pervious concrete, metakaolin, compressive strength.

RESUMEN

El hormigón permeable es un tipo de hormigón poroso de peso ligero sin finos o con un pequeño porcentaje de áridos finos. Se utiliza generalmente para aplicaciones de explanación, lo que permite que el agua de las precipitaciones y otras fuentes pase directamente, reduciendo así la escorrentía de un sitio y permitiendo la recarga del agua subterránea. Este estudio tiene como objetivo investigar experimentalmente las propiedades mecánicas e hidráulicas del hormigón permeable con diferentes niveles de sustitución de metacaolín. El hormigón permeable para aplicaciones de pavimento que tiene una porosidad de 20-25% con una relación cemento-agregado de 1: 4 y una relación a / c de 0,36 se establece en función de los parámetros de permeabilidad,

porosidad y resistencia. El metacaolín se incorporó al hormigón permeable reemplazando el cemento al 5%, 10% y 15% en peso de cemento, lo que ayuda a aumentar las propiedades mecánicas del hormigón permeable. Los parámetros de resistencia aumentaron aproximadamente un 12,24%, 23,95%, 13,97% para la resistencia a la compresión, la resistencia a la tracción dividida y la resistencia a la flexión, respectivamente, para el reemplazo del metacaolín al 10% y las propiedades hidráulicas disminuyeron a medida que aumentaba el porcentaje de metacaolín.
Palabras clave: hormigón permeable, metacaolín, resistencia a la compresión.

INTRODUCTION

Storm water management has become a prime factor for cities and municipalities due to urban sprawl. The impervious nature of conventional pavement system has led to an increase in storm water runoff quantity that has stemmed in a large volume of first flush containing unacceptable level of pollutants and flooding [2]. Pervious concrete is a special type of concrete characterized by a pore structure and high void content, which allows percolation of water through its structure. It is different from the conventional concrete because it contains a nominal or no amount of fine aggregate. It is also known as permeable concrete, porous concrete or no-fine concrete [5]. It has been used in low traffic pavements such as parking lots and sidewalks. Primary design objective of pervious concrete is to increase its permeability without much compromising of its compressive strength. Generally, the pervious concretes have water-cement ratio from 0.26 to 0.45 and fine aggregate between 0% and 10%. Connecting voids in pervious concrete ranging in size between 2 and 8 mm and voids ratio between 15% and 35% with water permeability of 2–12 mm/s. The high voids ratio of pervious concrete leads to compressive strength less than that of conventional concrete and it is ranging from 3 to 28 MPa[14]. Production of Portland cement causes many environmental problems. The carbon footprint can be reduced by replacing the cement with supplementary cementitious materials. Metakaolin is an anhydrous calcined form of the clay mineral kaolinite. Minerals that are rich in kaolinite are known as china clay or kaolin. It is the most effective pozzolanic material. It possesses a high reactivity with calcium hydroxide having the ability to accelerate cement hydration. Metakaolin reacts with the calcium hydroxide during the hydration process of PPC to form the calcium silicate hydrate (C-S-H) gel, it is very effective pozzolanic materials and effectively enhances the strength parameters of concrete[7].

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MATERIAL AND METHODS

The method adopted for this study is as follows:

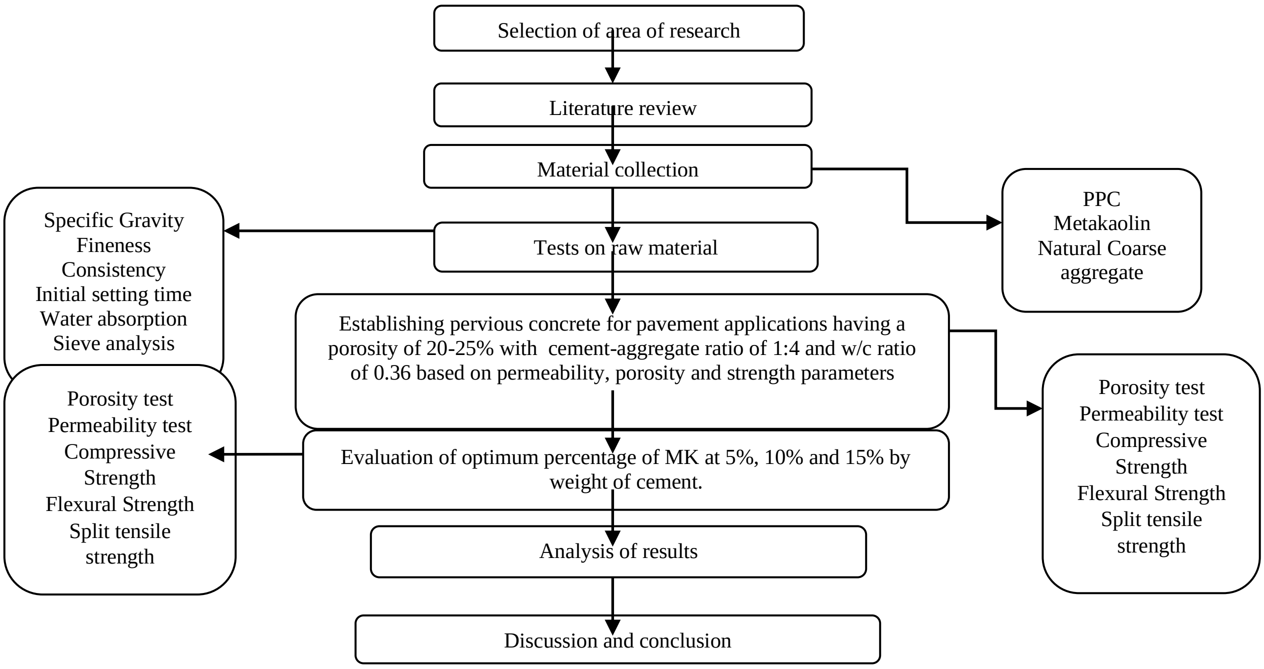

Fig 1: Flowchart of Methodology

MATERIALS AND PROPERTIES: The materials used in the experimental study are, cement (PPC), metakaolin as replacement material for cement, coarse aggregate and recycled coarse aggregate as replacement material for natural coarse aggregate. In the present experimental work, Portland pozzolana cement was used confirming to IS 1489:1991 (Part 1). Cement is generally used as the main binder material. Metakaolin is an anhydrous calcined form of the clay mineral kaolinite. It is the most effective pozzolanic material. The coarse aggregates are generally crushed stones with size ranging from 20 mm to 4.75 mm. They occupy around 70% of the total volume of concrete. The coarse aggregates used were with a nominal size of 12 mm downgraded crushed aggregates. The properties of coarse aggregates were confirming to IS 383:1970 (Reaffirmed 2016). Water is an important ingredient of concrete, as it actively participates in the chemical reaction with cement. The strength of cement concrete comes from the bonding action of the hydrated cement gel. Table 1 gives the various tests and properties of the materials.

Table 1: Materials and Properties

Material	Experiment	Result
Cement	Specific gravity	3.2
	Initial setting time	40 minutes
	Consistency	33%
Natural Coarse aggregate	Specific gravity	2.65
	Water absorption	0.72%
	Fineness modulus	2.49
Metakaolin	Specific gravity	2.6

MIX DESIGN: The mix was designed as per ACI 522R. The cement was replaced by metakaolin by weight. The proportions of components in the pervious concrete in each mix are given in table 2.

Table 2: Mix proportions

Mix	Nomenclature	Proportion
Pervious concrete	PC	1:4:0.36
Pervious concrete containing 5% Metakaoilin	PCMK5	0.95:0.05:4:0.36
Pervious concrete containing 10% Metakaoilin	PCMK10	0.9:0.1:4:0.36
Pervious concrete containing 15% Metakaoilin	PCMK15	0.85:0.15:4:0.36

CASTING AND TESTING: Cubes, cylinders and beams are casted for different mix proportions of pervious concrete and are tested for 7 and 28 days.

Fig 2: Casted specimens

RESULTS AND DISCUSSIONS

Compressive strength-The influence of metakaolin replacement levels on pervious concrete compressive strength is shown in figure 3. The test is carried out on cubic specimens of size 150x150x150mm. Each specimen is tested for 7 and 28 days. It is clear that the use of metakaolin has a significant effect on compressive strength due to the pozzolanic effect where increase in metakaolin content to a certain extend increases the compressive strength of different mixes of pervious concrete. 10% metakaolin content gives the maximum compressive strength of 27.668 N/mm² at 28 days which is 12.24% more when correlated to control mix.

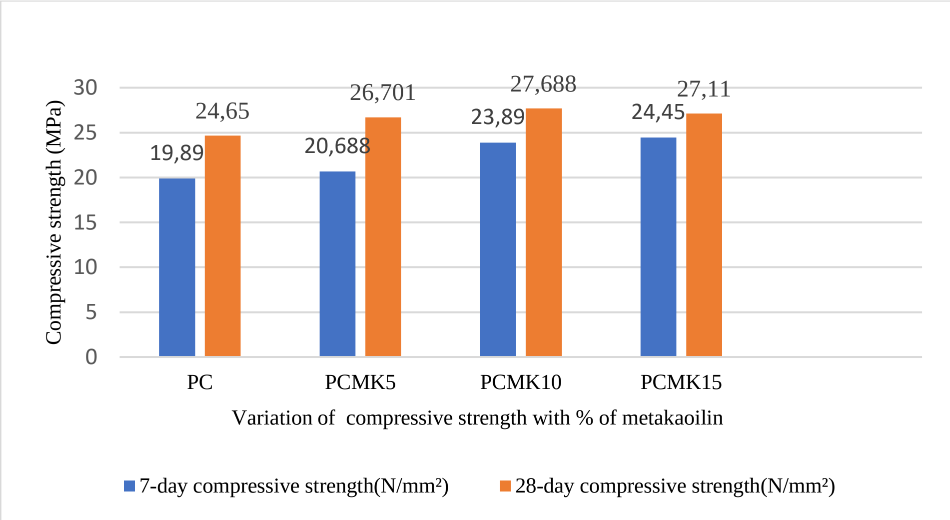

Fig 3: Variation of compressive strength of pervious concrete with varying % of metakaolin

SPLIT TENSILE STRENGTH: Figure 4 shows the influence of metakaolin replacement levels on pervious concrete split tensile strength strength. The test is carried out on cylinderical specimens of size 150x300mm. Each specimen is tested for 7 and 28 days. Due to the pozzolanic effect of metakaolin the split tensile strength increases as the metakaolin content increases to certain extend. Maximum strength of 2.37 is gained at 10% metakaolin replacement at 28 days and this mix gives 23.95% increase in split tensile strength when compared to control mix.

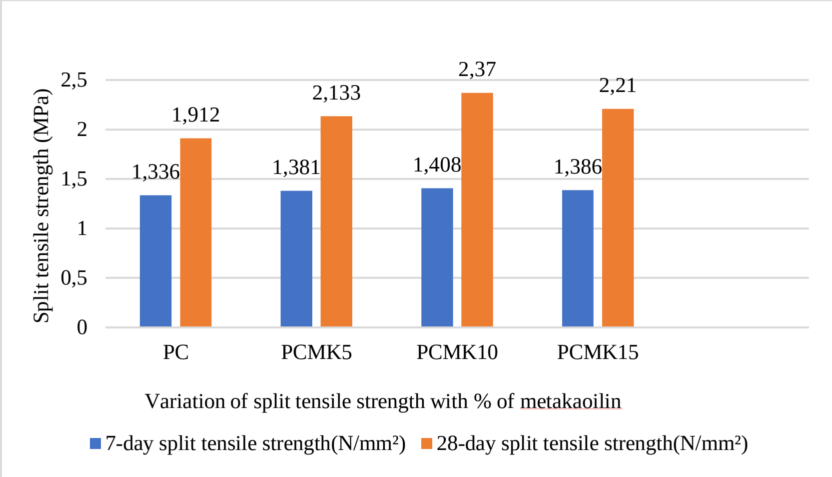

Fig 4: Variation of split tensile strength of pervious concrete with varying % of metakaolin

Flexural strength-The influence of metakaolin replacement levels on pervious concrete flexural strength is shown in figure 5. The test was conducted as per IS 516:1959 (Reaffirmed 2013) in Universal testing machine. Each specimen is tested for 7 and 28 days. The use of metakaolin is having a significant effect on flexural strength due to the pozzolanic effect where increase in metakaolin content to a certain extend increases the flexural strength of pervious concrete. 10% metakaolin content gives the maximum compressive strength of 3.1 N/mm² at 28 days which is 13.97% more when correlated to control mix.

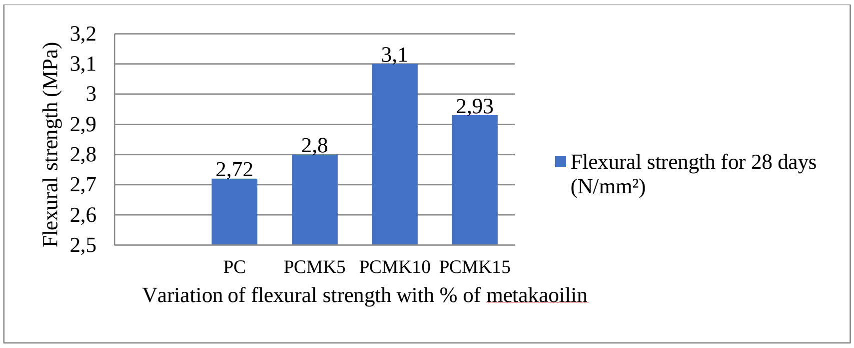

Fig 5: Variation of flexural strength of pervious concrete with varying % of metakaolin

PERMEABILITY: Figure 6 shows the influence of metakaolin replacement levels on pervious concrete water permeability. Water permeability for different pervious concrete mixes was determined by using falling head permeability method. From the test results, the permeability decreased about 11%, 30% and 67% for 5%, 10% and 15% metakaolin replacement respectively when compared to the control mix. Use of metakaolin in pervious concrete gives certain densification of the microstructure of concrete due to the pozzolanic reaction and filler effect which leads to greater impermeability.

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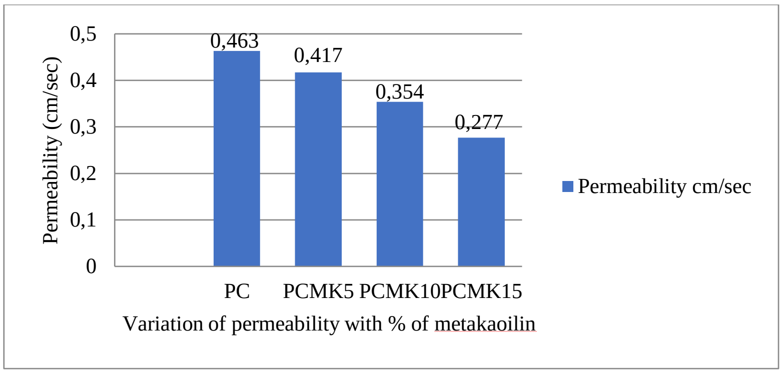

Fig 6: Variation of permeability of pervious concrete with varying % of metakaolin

POROSITY: Figure 7 shows the influence of metakaolin replacement levels on porosity of pervious concrete. The porosity of the pervious concrete was evaluated in accordance with ASTM C1754 (2012). From the test results, the porosity decreased about 8.8%, 15.2% and 28.3% for 5%, 10% and 15% metakaolin replacement respectively when compared to the control mix. The decrease in porosity also may be attributed to the filling effect of metakaolin.

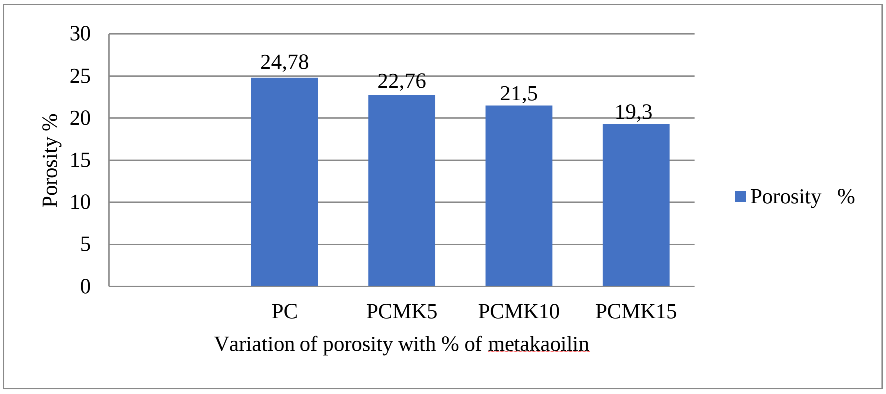

Fig 7: Variation of porosity of pervious concrete with varying % of metakaolin

As conclusion, experimental study on the effect of alternative material such as metakaolin in pervious concrete was conducted. This work was intended to analyse the mechanical and hydraulic properties of pervious concrete prepared with partial replacement of cement with metakaolin. The control mix was prepared with a porosity of 20-25%, cement to aggregate ratio of 1:4 and water cement ratio of 0.36. In case of pervious concrete with 10% metakaolin compared with control mix, the compressive strength increased about 12.24% (24.65-27.668 MPa), split tensile strength increased about 23.95% (1.912-2.37 MPa), flexural strength increased about 18.9%(2.72-3.1 MPa) and permeability and porosity decreased about 30.7% (0.463-0.354 cm/sec) and 15.2% (24.78-21.5%) respectively at 28 days. The mechanical and hydraulic properties of pervious concrete with 10% metakaolin satisfy the requirements of pavement applications. The optimum amount of metakaolin was obtained as 10%. So the metakaolin addition can be adopted as a method to improve the strength parameters of pervious concrete.

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