EXPERIMENTAL INVESTIGATION ON SHEAR STRENGTH OF HIGH PERFORMANCE CONCRETE WITH METAKAOLIN UNDER DIRECT SHEARING

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Abstract- This dissertation describes an experimental investigation to evaluate the shear strength and behaviour of concrete. The main purpose of this investigation is to determine the direct shear strength of concrete using Metakaolin and to find out shear failures of the specimens which were tested under **Universal Testing Machine (UTM).** The specimen we use is **Push-off specimen** and in order to increase the performance and to identify the shear behaviour it has been used. Concrete is one of most extensively used construction materials in the world. Each year, the concrete industry produces approximately 12 billion Tonnes of concrete and uses about 1.6 billion Tonnes of PC worldwide. Indeed, with the manufacture of one tonnes of cement approximately 0.94 tonnes of CO2 are launched into the atmosphere. To reduce the environmental impact of cement industries, MK and other cementations materials are used to replace part of cement or as a source of new cement less materials. Since Metakaolin posses the cementations properties it is being used as a partial replacement for the cement. Here 10% 20% 30% of Metakaolin have been used as a partial replacement for cement in the concrete. High performance concrete mix design is being used here to find the shear behaviour since shear required more strength to withstand the ultimate load. Cubes and cylinders are casted and tested to find the compressive strength and split tensile strength of the concrete. Four specimens are casted with side reinforcement to indentify the shear capacity between them. it helps is better understanding of the shear displacement. Four push off specimen are casted and cured for 28 days and tested in the universal testing machine or LVDT testing machine. From the results we get in the shear test the best percentage of replacement is experimentally studied the procedure involves casting, de-Moulding, curing and testing. In order to observe shear failure accurately the curing of the specimen should be done for 28days. Moreover, throughout the study **using of steel fibres with concrete gives more durability, strength and long life-span.**

KEYWORDS: Push off specimen, Shear strength, Metakaolin

I. Introduction

Concrete is one of the most extensively used construction material in the world with two billion tons placed worldwide each year. During the past few decades the potential of Portland cement in terms of its effective performances has been enhanced through the use of Supplementary Cementitious Materials (SCM). Also, as environmental concerns, stemming from the high energy expanse and CO_2 emission associated with cement manufacture, have brought about pressures to reduce cement consumption through the use of SCMs. As a result, the use of new admixtures has dramatically increased within the concrete industry. To know the shear behaviour of Structural elements in both reinforced and unreinforced concrete, such as columns and beams in tangential action, it is necessary to consider the pure shear acting either alone or with tension.

The research focuses on the mechanism of shear transfer in concrete alone by developing an experimental procedure. To determine the influence of the orientation of the surface of the shear failure on the force slip relationship. Indeed the major difficulty lies in developing an experimental procedure scientifically reliable to adequate. The push-off specimen is most widely used to study the influence of direct shear strength. It represents the shear behaviour of concrete and relatively easy for industrial purpose. Cement is one of the most energy intensive construction material and its production involves very high temperature(1400ºC to 1500ºC)processing an leads to the uncontrolled quarrying of natural resources and emission of CO2(greenhouse gas).Many efforts are being made to reduce the use of Portland cement in construction.

These efforts include the utilization of supplementary cementations materials as well as use of alternate materials in place of Portland cement. Civil engineers have to design and construct more durable structures for sustainability. Thus, design methods are needed to prevent harmful cracks in concrete under service loads. In the event that concrete member is subjected to an excessive shear load, the concrete sustains an initial crack, and the crack then propagates within the concrete member. Therefore evaluating the shear property of concrete elements in detail must be important.. A simple test method for concrete elements has been developed for evaluation of shear cracking and may contribute to shear design studies using new reinforcing materials. The simplified testing method for pure shear employs only simple jigs and a universal testing machine. The testing method converts un-axial load in to shear force and can provide shear forces to each side of a square concrete element.

II. Direct shear strength

Direct shear strength test were carried out on push-off specimen of size **700mm x 300mm x 120mm** at the age of 28days curing, using **100 tonne capacity UTM TUE-C-1000** Instrument. Shear strength of concrete is determined by push-off specimen mould suggested by ACI material journal **ACI, Vol.94 No.6 p.p.592-601.** The specimen was tested with side-face reinforcement.

Beam specimens of size **1500mm x 100mm x 150mm** in at the age of 28days curing and being tested to find the flexural strength.

III. Objective

This study attempts to estimate the shear strength of Push-off specimen. By considering and using **Metakaolin** as replacements material and to observe the different modes of Shear failure.

It shows the required design mix **(M40)** to gain required shear strength in structure under various methods. By this study structures are constructed with minimum shear failure at low cost.

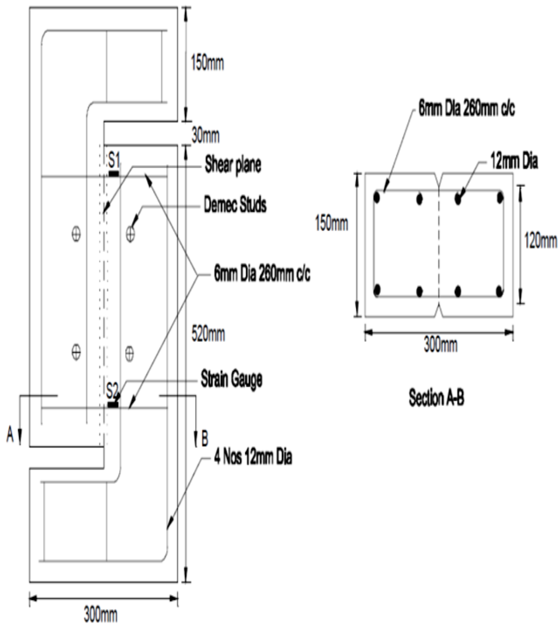

Figure 1: Detailing of push off specimen

IV. Material investigation

Cement is a binder, a substance used in construction that sets and hardens and can bind other materials together. In this project **53grade OPC** is used for experimental study. Generally 53grade cement is a prime brand cement with a remarkably high C3S (Tri Calcium Silicate) providing long-lasting to concrete structures.

Construction aggregate, or simply "aggregate", is a broad category of coarse particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geo-synthetic aggregates. Aggregates are the most mined materials in the world. Aggregates are a component of composite materials such as concrete and asphalt concrete; the aggregate serves as reinforcement to add strength to the overall composite material.

Aggregates are inert granular materials such as sand, gravel or crushed stone that are an end product in their own right. They are also the raw materials that are an essential ingredient in concrete.

The maximum size of coarse aggregate used was 20mm. coarse aggregates are particle greater than 4.75mm, but generally range between 9.5mm to 37.5mm in diameter. They can either be from primary, secondary or recycled source.

High-Reactivity Metakaolin (HRM) has been recently identified as a new mineral admixture that confirm to ASTM C 618, Class N pozzolan specification. Bureau of Indian Standards have recommended the use of Metakaolin in mortar and concrete as mineral admixture in IS: 456-2000.

HRM unique feature is that, it is not the by-product of an industrial process or an entirely natural material; it is derived from a naturally occurring mineral and manufactures specially for cementing applications.

It is fired (calcined) under carefully controlled conditions to create an amorphous aluminosilicate that is reactive in concrete. Like other pozzolans (fly ash and silica fume are two common pozzolans).

Metakaolin reacts with the calcium hydroxide (lime) byproducts produced during cement hydration. Calcium hydroxide accounts for up to 25% of the hydrated Portland cement, and calcium hydroxide does not contribute to the concrete's strength or durability.

Metakaolin combines with the calcium hydroxide to produce additional cementing compounds, the material responsible for holding concrete together.

Less calcium hydroxide and more cementing compounds means stronger concrete. It is very fine and highly reactive, gives fresh concrete a creamy, non sticky texture that makes finishing easier.

V. Experimental procedure

From the **M-40 grade** mix design the specimens were casted using controlled concrete and by using Metakaolin.

Table 1: Mix Proportions

Materials	Cement + MK (kg)	FA (kg)	CA (kg)	Water (kg)
Weight	402	972.61	1003.15	145
Ratio	1	2.419	2.495	0.36

The numbers of casted specimens are 4 under both shear in push-off specimen and flexure in Beams. The casted specimens are

Conventional (M40) - has been replaced with 10% of Metakaolin in both push-off specimen as well as beam specimen

Metakaolin (10%) – In this casting cement has been replaced with 10% of Metakaolin in both push-off specimen as well as beam specimen.

Metakaolin (20%) – In this casting cement has been replaced with 20% of Metakaolin in both push-off specimen as well as beam specimen.

Metakaolin (30%) – In this casting cement has been replaced with 30% of Metakaolin in both push-off specimen as well as beam specimen.

Compressive strength of concrete out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. By this single test one can judge that whether concreting has been done properly or not.

For the compression test the specimens are **150mm x 150mm x 150mm**. This concrete is poured in the mould and tempered properly so as not to have any voids. After 28 days these moulds are removed and test specimens are immersed in water for curing. The top surface of the specimens should be made even and smooth. This is done by putting cement paste and spreading smoothly on whole area of specimen.

These specimens are tested under compression testing machine after 28 days curing. Load should be applied gradually at the rate of **140kg/sq.cm per minute till the specimen fails**. Load at the failure divided by the area of specimen gives the compressive strength of concrete. Mix the concrete either by hand or in a laboratory batch mixer.

Similarly split tensile strength for other Metakaolin replacements have been carried out to find those values.

VI. Shear test

The device consists of a fixed lower part and an upper mobile one. A constant vertical force is applied on top of the shear box and a horizontal force is applied on the mobile part of the box.

During the shear test, the horizontal and vertical displacements a well as the forces are completely controlled. The box dimensions are **700mm × 300mm × 120 mm**. This model can be adapted to concrete specimens.

The main disadvantage of using such a test for the shear of concrete is the presence of gaps between the concrete and the inner wall of the shear box because of the phenomena of hardening and shrinkage of concrete after casting.

So, the poor contact between the specimen and the box can lead to a non-uniform distribution of stress and affects the nature of the results.

In addition, the friction between the lips of the crack after the peak leads to a stiffening behaviour of the structure and does not reflect the behaviour in brittle shear despite the full opening of the crack.

As the applied load increases on a beam, the location and orientation of shear cracks change. Furthermore, crack width and crack angle are not constant along a crack. For this reason, the strains in the reinforcing elements, such as steel stirrups, are not uniform along the crack.

The concrete contribution to shear strength and determine the inclination of the compressive strut within the variable truss model for slender RC shear-critical beams with stirrups using the modified compression field theory in place of the conventional statistical regression of experimental data,

The expression for the concrete contribution to shear strength was derived, and the inclination of compressive struts was determined.

A simplified explicit expression for shear strength was then provided, with which shear strength can be calculated without extensive iterative computations.

This method was then verified using the available experimental data of 209 RC rectangular beams with stirrups and compared with the current methods from the American Concrete Institute and the Canadian Standards Association.

The test specimens are stored in moist air for 24hours as a initial settling time period of concrete and after this period the specimens are marked and removed from the moulds and kept submerged in clear fresh water under the curing tank temperature until taken out prior to test.

Table 2: Workability test results

Sl.No	Specimen	Slump (mm)
1	Conventional (M40)	50 mm
2	Metakaolin (10%)	52 mm
3	Metakaolin (20%)	51 mm
4	Metakaolin (30%)	53 mm

Table 3: VEE-BEE Results

Sl.No	Specimen	Vee-bee degree
1	Conventional (M40)	14
2	Metakaolin (10%)	12
3	Metakaolin (20%)	15
4	Metakaolin (30%)	13

The comparative study on Metakaolin is done to obtain the different shear strengths and their properties. We have casted 4 combinations at the age of 28days curing.

The comparative study is done because every by-product has its own characteristics and their properties and in order to differentiate it the study has been done.

we have done and this research mainly focuses on how the by-product materials has been used in the concrete, how it works while it gets mixed, at what range the shear strength values gets differed, and finally by using a particular combination we can deduct failure obtain more strength to the structure and economically also it works

Table 4: Compaction Factor results

Sl.No	Specimen	Compaction factor
1	Conventional (M40)	0.82
2	Metakaolin (10%)	0.85
3	Metakaolin (20%)	0.9
4	Metakaolin (30%)	0.81

Table 5: Cube compressive strength results

Sl.No	Specimen	compression
1	Conventional (M40)	46 N/mm^2
2	Metakaolin (10%)	46.5 N/mm^2
3	Metakaolin (20%)	47 N/mm^2
4	Metakaolin (30%)	46 N/mm^2

Table 6: Split Tensile strength results

Sl.No	Specimen	Tensile strength
1	Conventional (M40)	3.97 N/mm^2
2	Metakaolin (10%)	4.2 N/mm^2
3	Metakaolin (20%)	5.3 N/mm^2
4	Metakaolin (30%)	4.3 N/mm^2

Fig 2 Push-off Specimen Mould

Fig 3 Beam & Shear Moulds With Reinforcement

Fig 4 Casting of Push-Off Specimen

Fig 5 Testing of Push-Off Specimen

Table 7: Failure Load of Push-Off Specimen

Sl.No	Specimen	Failure Load (KN)
1	Conventional (M40)	85.5
2	Metakaolin (10%)	87
3	Metakaolin (20%)	98.5
4	Metakaolin (30%)	83

Table 8: Shear Strength of Push-Off Specimen

Sl.No	Specimen	Shear Strength
1	Conventional (M40)	2.375 N/mm^2
2	Metakaolin (10%)	2.417 N/mm^2
3	Metakaolin (20%)	2.736 N/mm^2
4	Metakaolin (30%)	2.305 N/mm^2

Fig 6 Casting of Beam Specimens

Table 9: Flexural Strength of Beam Specimens

Sl.No	Specimen	Flexural strength
1	Conventional (M40)	6.9 N/mm^2
2	Metakaolin (10%)	7.2 N/mm^2
3	Metakaolin (20%)	7.5 N/mm^2
4	Metakaolin (30%)	7.0 N/mm^2

Fig 7 Testing of Beam Specimens

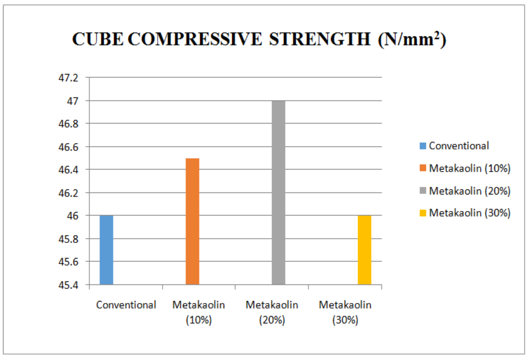

Fig 8 Cube Compressive strength Results

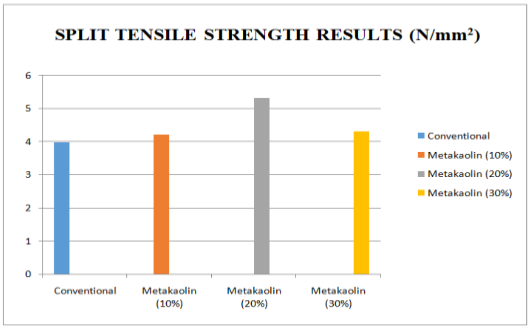

Fig 9 Split tensile strength Results

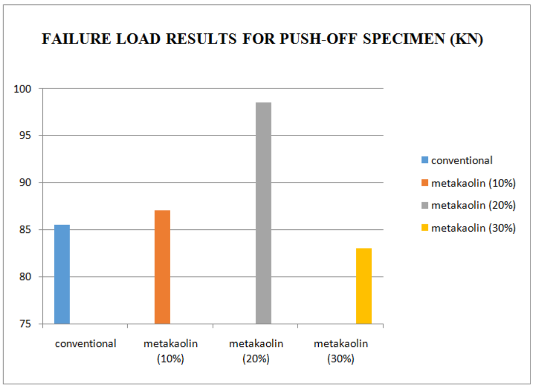

Fig 10 Failure load for push-off specimen

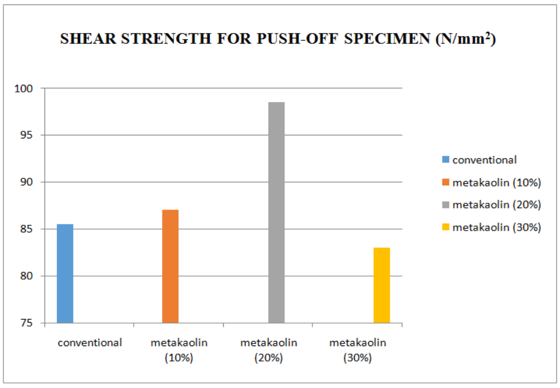

Fig 11 shear strength Results

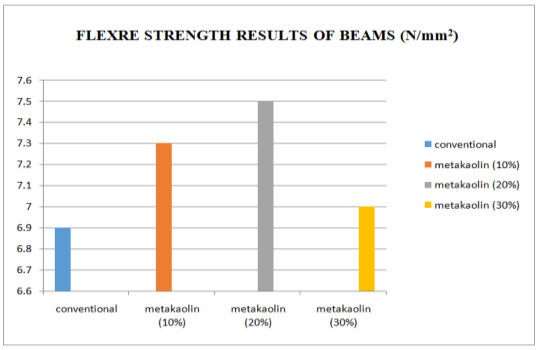

Fig 12 Flexural strength Results

VII. Conclusions

Based on the results of experimental investigations in this thesis, the following conclusions can be made, and to find the best one from them.

- The required shear strength are achieved in concrete with Metakaolin.
- A significant increase in shear strength is achieved by incorporating optimum quantity of Metakaolin in High performance concrete.
- Among all the replacements being used in this experimental work **20 % replacement of Metakaolin** gives Better performance when compared with other replacements.
- 10% Replacement of Metakaolin gives slight increase in cube compressive strength as well as split tensile strength
- 20% Replacement of Metakaolin decreases the formation of shear cracks when compared with conventional, MK (10%) & MK (30%).
- Coming to the Beam Results, Flexural Cracks are decreases with 20% replacement of Metakaolin.
- Here by the above results concludes that Metakaolin with 20% replacement shows better results than other specimens.
- Thus the investigation made with Metakaolin proves that it is suitable substitute for the replacement of cement.

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