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Comparative Study on the Behaviour of Geopolymer Concrete with Hybrid Fibers under Static Cyclic Loading

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Abstract

Geo-polymer is a latest advancement in which the cement is substituted by an eco-friendly Pozzolanic material. It is activated by a highly alkaline solution to produce aluminosilicate gel which acts as a binder in concrete. In this study cement is fully replaced by Ground Granulated Blast Furnace Slag (GGBFS). Since concrete is fragile steel and glass fibres are supplemented to improve the performance of the concrete. These hybrid fibres are optimised by compression test and split tensile test. The flexural behaviour of the conventional concrete and a geo-polymer concrete is tested under static cyclic loading for the corresponding optimised percentage of hybrid fibres. The experimental test shows significant improvement in the flexural strength, stiffness degradation, cumulative energy dissipation capacity, displacement ductility and the ultimate load with its corresponding deflection.

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Keywords: Geo-polymer Concrete; Ground Granulated Blast Furnace Slag; Steel Fibres; Glass Fibres; Static Cyclic Load

1. Introduction

Ordinary Portland Cement (OPC) being a significant material in the production of concrete form an indigenous substance to bind aggregates. The manufacturing of OPC necessitates firing a large quantity of fuel for the decomposition of limestone, resulting in the emission of carbon dioxide [1]. The production of cement causes pollution to the environment and subsequently leads to the depletion of raw material (limestone). Kong., [1] suggested the activation process for a pozzolanic material that is rich in silica and alumina (fly ash) with an alkaline

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element at a certain elevated temperature. Fly ash when comes in contact with a highly alkaline solutions forming an inorganic alumino–silicate polymer product yielding polymeric Si–O–Al–O bonds known as Geopolymer [2].

Silica and alumina atoms react to form molecules that are chemically and structurally equivalent to a natural rock [3]. It shows an enhanced bonding property, better abrasion and high impact resistance with less susceptible to chemical attack [4]. The use of geopolymer reduces CO_2 emission there by helps in minimizing the ecological impact caused by the construction industry. Investigation on the properties of the geopolymer concrete (GPC) was carried with a combination of flyash and ground granulated blast-furnace slag and it is observed that such concrete has strength similar to that of the Portland Cement Concrete with a better durability [5]. Geopolymer concrete can also be used at elevated temperatures without significant loss in the mechanical properties of the concrete [6].

The conventional method of increasing the shear capacity in a beam is to provide a closely spaced transverse reinforcement. Which can increase the shear capacity to a certain extent and it will create congestion in reinforcement. An alternative technique to overcome this difficulty is to use the randomly distributed steel fiber in reinforced concrete. This steel fiber (SF) helps as a bridging element to arrest the propagation of the crack [7-9]. To reduce the chemical attack and to increase thermal insulation [10] in concrete glass fibers (GF) were added.

The brittle catastrophic failure in concrete under cyclic loading is of immense importance in seismic design. To reduce the ecological impact on environment nowadays cement is replaced by Pozzolanic material. Hence, this study explores the possibility of using the steel fiber and glass fiber in geopolymer concrete and testing it under static cyclic loading to obtain the load-deflection graph. The comparisons were made in terms of load deflection behavior, displacement ductility, stiffness degradation and energy dissipation capacity. These investigations will provide additional information for the usage of reinforced GPC with hybrid fiber (HF) in a structure subjected to cyclic load.

2. Experimental Investigation

2.1. Overview

The project deals with the comparative study on the behaviour of an eco-friendly geopolymer concrete and a conventional concrete (CC) with hybrid fibres (HF) under static cyclic loading. The HF used in this study is a combination of steel fibre and glass fibres. The beam specimens were casted for an optimum value of hybrid fibres (HF) obtained from compression test on cube and split tensile test on cylinder.

The specimens were fabricated with optimum value of hybrid fibre and tested under static cyclic loading. The study comprise the comparative behaviour of conventional and geopolymer specimen with hybrid fibre under static cyclic loading in terms of load deflection behaviour, ductility, degradation in stiffness and energy absorption capacity.

Table 1. Mix proportion of conventional and geopolymer concrete

Materials (kg/m^3)	Conventional concrete	Geopolymer concrete
Cement	438	---
GGBS	---	394
Fine aggregate	651	600
Coarse aggregate	1129.46	1248
Solution	197	97

2.2. Material specification

To find the optimum replacement of hybrid fiber a conventional concrete grade of M30 mix designed as per Indian standards and a Ground Granulated Blast Furnace Slag (GGBS) based geopolymer concrete mix designed for a characteristics strength of 30 N/mm^2 with constant value of Na_2SiO_3/NaOH=0.5 and SF⁄AL=0.25 [11] is used in this study. The details of the mix proportion are shown in Table 1. The mechanical properties of fibres used in this study were sorted in Table 2 and is shown in Fig. 1.