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GEOPOLYMER CONCRETE STEEL BAR REINFORCEMENT RESPONSE AGAINST EXPLOSIVE AIR BLAST

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Abstract

The application on non-cementious concrete are widely discovered for industry as to enhance the use of waste material, fly ash. Fly ash known as geopolymer binder which can improve the mechanical performance of the concrete and reinforcement impart strength to the concrete, relatively. Reinforcement correlate improvement in the blast resistance when retrofitted with the steel bar and fibres. The levels of damage after the blast explosion rely on the types of reinforcement in the concrete matrix. Meanwhile, the mass of explosive and distance of explosive to the concrete beam used in experiment field also affect the level of damage after blasting. The 3 beams was tested in the field blast experiment by using different scaled distance that are 0.298 m/kg1/3 , 0.224 m/kg1/3 and 0.149 m/kg1/3. Impulsive impact from the explosive detonation with the lowest scaled distance bring the most effect against the concrete. This paper represent the geopolymer concrete beam with steel bar reinforcement response towards explosive air blast loading.

Keywords*: geopolymers, fly ash, reinforcement, explosion, concrete, steel bar, fibers.*

Introduction

The solid waste material from coal burning industry, fly ash were used in cement and concrete composites. It can be formed by the reaction of alkaline activator for instance aluminosilicate material and alkaline solutions [1, 2]. An extensive research has been investigated the most frequent used in a mixture as an activating solution is sodium hydroxide (NaOH) and waterglass (Na2SiO3) [3-5]. Furthermore, the higher concentration of NaOH provoked high alkalinity caused inter reaction between the two components, Si and Al, that insult the bridge glassy chain of fly ash [7, 8]. After dissolution, the geopolymer paste act as binder to the coarse aggregates, fine aggregates and reinforcement together to form geopolymer concrete via geopolymerization process [6]. During the middle phase, continuity reaction occur until the C-S-H gel formation phase formed while water completely release, the hardening of concrete were take places [9].

Based on the laboratory data, reported that fly ash cement can harden rapidly at room temperature and exhibited high compressive strength in the range 20 MPa after only 4 hours. While the compressive strength of geopolymeric cement is resulted as 80 MPa after curing at 28 day. It was reported that, there were several factors mainly interrelated with compressive strength such as curing time and temperature, solid to liquid ratio and water amount in the mixture [10]. Moreover, reinforcement concrete also can be raise the value of tension and

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compression strength of concrete due to ductility and capability to exhibit lower modulus of elasticity [12, 13].

The concrete is a very easily affect strain rate material as it showed higher fracture energies and also higher impacts strength [13]. High impact energy deteriorate the concrete structural as well as lower the mechanical behaviour [15, 16]. The severity of damage and injuries by the cause of explosion cannot be assumed with simple assumption [16]. As a result, there were some parameters to be expected in the blasting phenomenon based on the standoff distance, size and type of explosion and shape of charges [18–20]. Limited study has been proposed on the blast resistance of reinforce concrete beams, column, slabs, concrete walls and masonry walls using geopolymer concrete.

Design of experiment setup

Concrete Reinforcement Design

The incorporation of concrete fiber reinforcement material such as glass, nylon, steel, carbon and polypropylene can increase its mechanical properties, including its ductility, crack and impact resistance, tensile strength, stiffness, ductility, fatigue life, durability, and shrinkage reduction capability [12]. From the former researchers revealed that, the arrangement of the reinforcement can reduce the damage degree of the concrete structure [14] and optimal arrangement also able to minimize the ballistic resistance [20]. Fig. 1 shows the cross section view of concrete beam with Y10 steel rebar grade B500BT with a nominal yield at 500 MPa. The threaded reinforcement concrete surface geometries and mechanical behaviour are not similar because it bonding tightly to concrete compared to unthreaded steel bars. Research which have been developed over three decades also proved, energy absorption capacity can be improve by enhancing fiber that have high stress transfer capability and impact resistance [21].

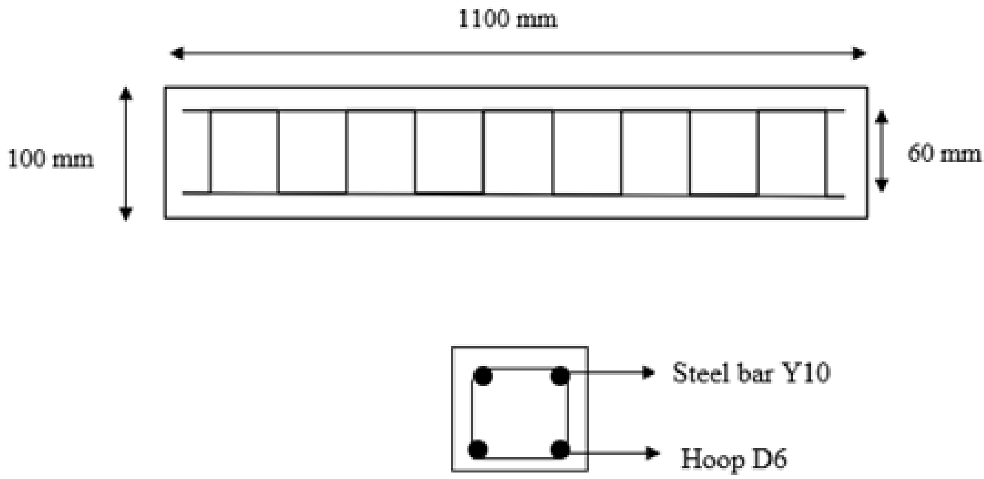

Fig. 1. Cross section view of concrete beam with reinforcement

Blasting events

Air blast detonations events on concrete purpose were studied as to perform experimental data. This measurement data will compute into modelling of concrete target towards blast in the action of dynamic loading. Table 1 shows the parameter used in field blast experiment using emulex esplosive. Fig. 2 indicated that illustration design for a blast test comprised of simply support blocks, displacement needles and an explosive at mid span of the beam.

Table 1. Parameters for field blast experiment

Beam	Mass of explosive, W (gram)	Standoff distance, R (mm)	Scaled distance ($Z= R/\sqrt[3]{W}$) ($m/kg^{1/3}$)
Beam 1	300	200	0.298
Beam 2	300	150	0.224
Beam 3	300	100	0.149

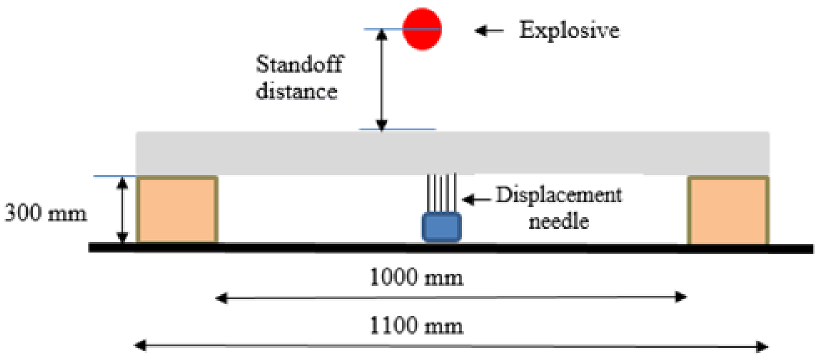

Fig. 2. Illustration for field blast test

Damage assesement

The duration of the blasting events occurs in very short time, measured in milliseconds per detonation. In addition, the open air detonation is the primary damage mechanism because of the shock wave produced. This can be known as, damage due to direct air blast effects and progressive collapse. The damage generated from the blast loading usually encountered from this blasting events are crack mitigation, concrete spallation, flexural strength failure and deflection collapse.

Crack propagation

As a result, the rate of crack propagates rapidly at higher stress rate, thus cause the zone of micro cracking become bigger. The cracks width is decreased while the number of cracks increased as the compressive strength of the beam is higher. The main cracks perforates through the shock waves reflected on top and bottom of the surface endlessly. It is observed that the involving of tensile and compressive cracks is the primary factor of crack propagation. From the experimental results as shown in Fig. 3, there are two cracks pattern as initial cracks at the bottom of the beam and parallel cracks for bending failure located at sides of the beam.

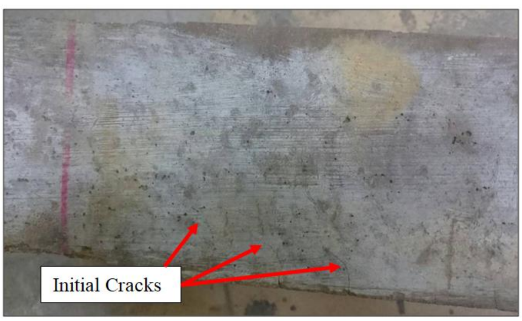

Fig. 3. Crack on the beam after exposed to air blast

Concrete spallation

The mechanism for formation of concrete spallation is when the shock wave reflects frequently as compressive pressure towards the concrete surfaces, the tensile wave also have a tendency reflects oftentimes on the bottom surface. This effect the concrete spallation occurs at the bottom when the tensile pressure wave reflected as shown in Fig. 4. The top side will leads to the horizontal cracks due to back and forth pressure from the open air explosive detonation. The bottom side of the beam will encounter the tensile failure as the impulsive force acting upside the beam.

a) Compressive failure b) Tensile failure

Fig. 4 Post blast concrete spallation damage

Deflection rate and flexural failure

As stated from the experiment, the concrete crushing in the compression region can caused the flexural failure and deflection rate increased. It was also examined that the present of steel bar reinforcements avoided shear cracks to develop, thus, increasing the shear strength of the beams and resulting in a more ductile failure. After detonation, beams deflected till contact the steel needle downward into sand as shown in Fig. 5, thus deflection rate are calculated by computing the value of maximum deflection. Table 2 shows the result on deflection and level of damage of the beam. The beam with the lowest scaled distance is observed to have more damage and high deflection rate compared to highest scaled distance.

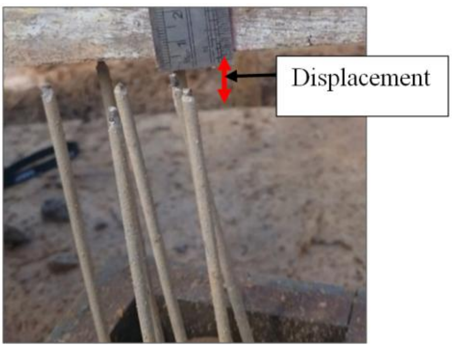

Fig. 5. Sketch maximum displacement by steel needle

Table 2. Deflection result after blasting

Beam	Scaled Distance, Z (m/kg$^{1/3}$)	Deflection (mm)	Observation
Beam 1	0.298	2.0	No damage
Beam 2	0.224	5.0	No damage
Beam 3	0.149	7.0	Damage at top and bottom

Conclusions

From the conclusion, the importance of a concrete reinforcement design being able to sustain concrete members towards the impact explosion. The durability of the geopolymer concrete can be tested by adjusting the scaled distance during blast field event. If this ability was not analyses, blast loaded concrete structures may cause the shear cracks and engineering failure. By using fly ash as the replacement material, it was proved that better performance of the strength of concrete compared to OPC. In addition, a broader studies about awareness in public area and land defense concerns has increased the need to support the development of new and more affordable upgrade technologies.

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