FAILURE ASSESSMENT: COMPARISON OF THE FAILURE MODE BETWEEN OPC MIC AND FIBER MIX CONCRETE SLAB

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ABSTRACT

This thesis is consisting about the comparison of failure assessment for OPC reinforced concrete slab and fiber added reinforced concrete slabs. The objectives of this thesis are to determine the ultimate load that can withstand by the slabs, the deflection of the slabs, and the crack pattern caused by punching failure. A total four slab samples with dimension of 1.6m × 0.8m × 0.15m are being constructed. The four samples are added with four different proportions of fiber. The first sample is not added any fiber as a control sample. 1.8kg of fiber per meter cube of concrete is added into the second slab samples. The third sample has 0.9kg of fiber per meter cube of concrete. The fourth sample has 0.45kg of fiber per meter cube of concrete. Load is applied at the center point of the samples until the samples are experiencing punching failure. The ultimate load and the maximum deflections occur during the ultimate load is measured. At the end of the experiment, mapping of the cracks occur at the bottom and side of the slab samples are carried out. The experimental results showed the amount of fiber added into the slab samples will affect the ultimate load and deflection of the samples. The data was analyzed and the conclusion is drawn that fiber with proportion of 0.9kg per meter cube of concrete contributes the highest ultimate load and the lowest deflection.

ABSTRAK

Tesis ini terdiri tentang perbandingan taksiran gagal untuk papak bertetulang OPC konkrit dan serat tambah papak konkrit bertetulang. Objektif tesis ini adalah untuk menentukan beban muktamad yang dapat menahan oleh papak, pesongan daripada papak, dan corak retak yang disebabkan oleh kegagalan menumbuk. Sebanyak empat sampel papak dengan dimensi 1.6m × 0.8m × 0.15m sedia dibina. Empat sampel ditambah dengan empat perkadaran yang berbeza serat. Sampel pertama tidak ditambah sebarang serat sebagai sampel kawalan. 1.8kg serat per kiub meter konkrit ditambah ke dalam sampel kedua papak. Sampel ketiga mempunyai 0.9kg serat setiap kiub meter konkrit. Sampel keempat mempunyai 0.45kg serat setiap kiub meter konkrit. Dikenakan beban pada titik pusat sampel sehingga sampel mengalami kegagalan menumbuk. Beban muktamad dan pesongan maksimum berlaku semasa beban muktamad diukur. Pada akhir eksperimen, pemetaan retakan berlaku di bahagian bawah dan sisi sampel papak dijalankan. Keputusan uji kaji menunjukkan jumlah serat yang ditambah ke dalam sampel papak akan menjejaskan beban muktamad dan pesongan sampel.Data yang telah dianalisis dan kesimpulan yang dilukis bahawa serat dengan bahagian 0.9kg satu meter kiub konkrit menyumbang beban tertinggi yang muktamad dan pesongan terendah.

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LIST OF SYMBOLS

R	-	Loading rate, in MPa (N/s)
s	-	Stress rate, in MPa/s ($N/mm^2.s$)
d_1, d_2	-	Lateral dimensions of the specimen, in mm. (see Figure 4.1)
l	-	Spacing of the lower rollers, in mm
f_{cf}	-	Flexural strength , in MPa (N/mm^2)
F	-	Maximum load, in N
l	-	Distance between the supporting rollers, in mm
Δ	-	Deflection, in mm
P	-	Applied load, in N
L	-	Length of the test specimen
$E_{c,t}$	-	Modulus of elasticity if concrete at an age *t* , in kN/mm^2 (according to BS 8110-1:1985, Part 2, clause 7.2)
I	-	Moment of inertia, in mm^4

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND INFORMATIONS

Reinforced concrete is a composite material that widely used in the world. It is used at almost every element in a building which is included foundations, slabs, beams, columns and retaining walls. As we know that, concrete is strong in compression but weak against tension or tensile forces therefore reinforcements are added to increase the tensile strength of concrete. There are various types of materials could be added as the reinforcements for concrete to increase the tensile strength. Reinforcement bar is the most common material added into concrete to solve the shortage of concrete. Reinforcement bars provide good tensile strength to concrete to resist the tension experienced by the concrete but the reinforcement bars are suffering a problem from corrosion of the steel by the salt, which results in the failure of those structures.

1.2 PROBLEM STATEMENT

The slabs are designed to withstand and transfers the loads from the upper parts of a building and imposed loads to the supporting beams without any structural failures. But a slab could crack during the transfer of the loads. In order to solve this problem, polypropylene fibre is added in to the concrete as the reinforcement to increase the capability of slab to resist the loads.

1.3 RESEARCH OBJECTIVES

i. To determine the ultimate load that can withstand by the slabs.
ii. To determine the deflection of the slabs.
iii. To determine the crack pattern caused by punching failure.

1.4 RESEARCH QUESTIONS

i. How to determine the ultimate load of slab?
ii. What is the deflection of slab under the ultimate load?
iii. How is the punching failure?

1.5 SCOPES

i. The grade of the concrete is 25 N/mm^2.
ii. The thicknesses of the slabs are 150mm.
iii. The size of slabs is 1.6m × 0.8m.

1.6 EXPECTED OUTCOME

i. Determine the ultimate load of the slabs
ii. Identify the deflection of slabs under the ultimate load.
iii. Observe the punching failures.

CHAPTER 2

LITERATURE REVIEW

2.1 FAILURE ASSESSMENTS

The failure assessments are consisting about the crack and deflection occurred, and the ultimate load withstand by the particular structure. Concrete structures deteriorate for reasons including internal reinforcement corrosion, freeze thaw action, excessive loading and poor initial design (H.N. Gardena't and L.C. Hollaway, 1998).

Structural failure is the fail of load carrying capacity of a particular member in a building or structure. The failures are occurred when the applied forces on the structure is beyond its designed strength limit, therefore it has caused the crack or fracture or deformations on the structure. In a well designed structure or system, a localized failure should not cause the immediate or progressive collapse of the whole building structure. The ultimate failure strength the most important point that to be taken account as the limit state for in structural engineering and also the structural design.

2.2 TYPES OF SLAB FAILURE

2.2.1 Crack

In concrete structures, cracks can be indicated as a principal issue or problem from the surface and the internal of the construction structures. Cracks can generally be categorized into three groups: (i) cracks due to inadequate structural performance, (ii) cracks due to inadequate material performance, and (iii) acceptable cracks. Structural cracks are caused primarily by overloading; material related cracks are due to shrinkage and chemical reactions; and acceptable cracks are those that normally develop due to service loading so that tensile stresses can be distributed properly along the length of the material, without hindering the long-term performance of concrete. Cracks in concrete structural elements can also be classified as dormant or active. Active cracks, such as cracks caused by foundation settlement, cannot be fully repaired, whereas dormant cracks can be successfully repaired (Hasan Nikopour and Moncef Nehdi, 2010).

For slabs, the crack formation has been identified as a problem in slabs. In the interior of slabs, the crack would occur at many, such as, at the corner of the slabs, at the centerline, and diagonally in between the opposite corners (J. K. Brimacombe and K. Sorimachi, 2007). Besides that, on the surface of the slabs, the crack could be appeared in the form of transversely and longitudinally at the middle part of the slabs, and as well as at the corners where near the supports of the slabs.

2.2.2 Deflection

Deflection in a member or can also be called as sag in member is the change in length of the member at its upper and lower parts. In a spanning member, the part which is under compression, the length will be shortened, whereas the tension zone will be experienced elongation.

Deflections of spanning members may be caused or significantly affected by many factors. Most prominent among these are:

- Elastic strains,
- Creep strains,

- Shrinkage,
- Temperature

2.2.2.1 Elastic strains

It is form of strain in which the distorted body returns to its original shape and size when the deforming force is removed.

2.2.2.2 Creep strains

When subjected to long-term loading all building materials experience "plastic flow" (or creep) strains that increase the total deflection when added to elastic strain.

2.2.2.3 Shrinkage

Shrinkage of concrete is the time-dependent strain measured in an unloaded and unrestrained specimen at constant temperature. It is important from the outset to distinguish between plastic shrinkage, chemical shrinkage and drying shrinkage.

2.2.2.4 Temperature

A temperature differential across a member causes a thermal expansion differential that produces or deflection. Deflections resulting from temperature differentials occur with all materials in proportion to their coefficients of expansion.

2.3 CAUSES OF SLABS FAILURE

Cracks are categorized as occurring either in plastic concrete or hardened concrete. There are many reasons or causes that bring about the failure of the slabs.

2.3.1 Cracking of plastic concrete

2.3.1.1 Plastic Shrinkage Cracking

When moisture evaporates from the surface of freshly placed concrete faster than it is replaced by bleed water, the surface concrete shrinks. Due to the restraint provided by the concrete below the drying surface layer, tensile stresses develop in the weak, stiffening plastic concrete. This results in shallow cracks of varying depths that may form a random, polygonal pattern, or be essentially parallel to one another (ACI Committee 224).

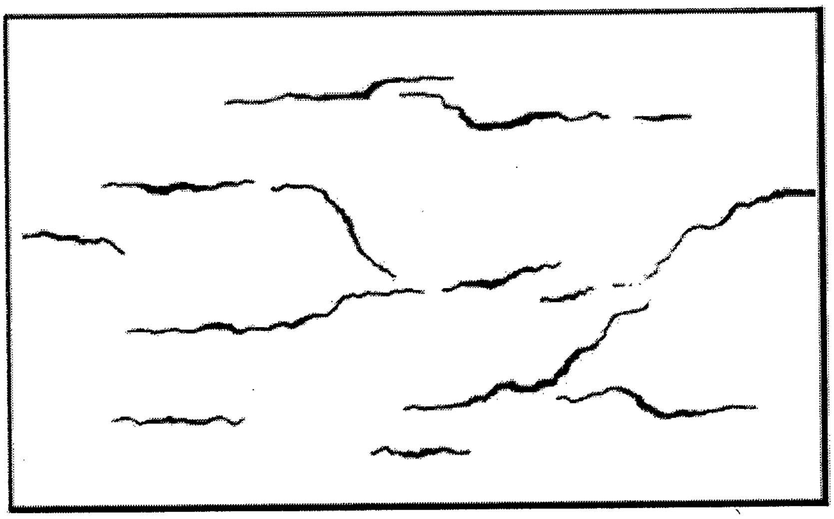

Figure 2.1 : Typical plastic shrinkage cracking

Source : ACI Committee 224

2.3.1.2 Settlement Cracking

Concrete has a tendency to continue to consolidate after initial placement, vibration, and finishing. During this period, the plastic concrete may be locally restrained by reinforcement bars, a previous concrete placement, or formwork. This local restraint may result in voids, cracks, or both, adjacent to the restraining element. When associated with reinforcing steel, settlement cracking increases with increasing bar size, increasing slump, and decreasing cover (ACI Committee 224).

2.3.2 Cracking of Hardened Concrete

2.3.2.1 Drying Shrinkage

A common cause of cracking in concrete is restrained drying shrinkage. Drying shrinkage is caused by the loss of moisture from the cement paste constituent, which can shrink by as much as 1%. Fortunately, aggregate particles provide internal restraint that reduces the magnitude of this volume change to about 0.06%. On the other hand, concrete tends to expand when wetted (ACI Committee 224).

2.3.2.2 Thermal Stresses

Temperature differences within a concrete structure may be caused by portions of the structure losing heat of hydration at different rates or by the weather conditions cooling or heating one portion of the structure to a different degree or at a different rate than another portion of the structure. These temperature differences result in differential volume changes (ACI Committee 224).

2.3.3.3 Weathering

The weathering processes that can cause cracking include freezing and thawing, wetting and drying, and heating and cooling. Damage from freezing and thawing is the most common weather-related physical deterioration. Damage in hardened cement paste from freezing is caused by the movement of water to freezing sites and, for water in larger voids, by hydraulic pressure generated by the growth of ice crystals. Aggregate particles are surrounded by cement paste, which prevents the rapid escape of water. When the aggregate particles are above a critical degree of saturation, the expansion of the absorbed water during freezing may crack the surrounding cement paste or damage the aggregate itself (ACI Committee 224).

2.3.3.4 Corrosion of Reinforcement

Corrosion of a metal is an electrochemical process that requires an oxidizing agent, moisture, and electron flow within the metal; a series of chemical reactions takes place on and adjacent to the surface of the metal (ACI Committee 224).

2.3.3.5 Errors in Design and Detailing

The use of an inadequate amount of reinforcement may result in excessive cracking. The effects of improper design or detailing range from poor appearance to lack of serviceability to catastrophic failure. Errors in design and detailing that may result in unacceptable cracking include use of poorly detailed re-entrant corners in walls, precast members, and slabs; improper selection or detailing of reinforcement, or both; restraint of members subjected to volume changes caused by variations in temperature and moisture; lack of adequate contraction joints; and improper design of foundations, resulting in differential movement within the structure (ACI Committee 224).

2.4 EFFECT OF FAILURES

The Versailles wedding hall (Hebrew: אולמי ורסאי), located in Talpiot, Jerusalem, is the site of the worst civil disaster in Israel's history. At 22:43 on May 24, 2001, during the wedding of Keren and Asaf Dror, a large portion of the third floor of the four-story building collapsed. As a result, 23 people fell to their deaths through two stories. This was based on the testimony provided by many of the wedding guests present in the building during the disaster. Witnesses reported seeing a dangerous sag in the wedding floor a short time before the collapse. An initial inquiry blamed the collapse on the Pal-Kalmethod of constructing light-weight coffered concrete floor systems.

Table 2.1: List of Structural Failures

Year	Structure	Location	Type
2011	Antenna mast of tower of Zendstation Smilde	Hoogersmilde, Netherlands	Partially guyed tower
2011	Enschede Stadium Roof Collapse	Enschede, Netherlands	Stadium roof
2009	Sultan Mizan Zainal Abidin Stadium	Terengganu, Malaysia	Stadium roof
2009	Palma de Mallorca House Collapse	Palma de Mallorca, Spain	Housing
2009	Jaya Supermarket	Petaling Jaya, Malaysia	Commercial
2007	Neurath Power Station Scaffold collapse	Grevenbroich-Neurath, Germany	Power station under construction

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In this chapter, types and amounts of materials needed to conduct the research, procedures to conduct the research, the equipments needed, and the arrangement of equipments and samples to conduct the research was shown and discussed. The materials needed to carry out this research are aggregate, water, cement, reinforcement bar, nails and plywood. While the equipment needed are strong floor apparatus, slump test apparatus, and concrete mixer, and concrete mould, compression testing machine, bar cutter machine, concrete vibrated, and jute.

Before we can determine the amount of material needed to carry out this research, we need to determine the dimension of the slab and the reinforcement to be used.

3.2 LIST OF MATERIALS AND INSTRUMENTS

3.2.1 Materials

a) Mega Mesh polypropylene fibre

b) Portland cement

c) 20mm Aggregates
d) Find sand
e) Reinforcement steel bars (Y12)
f) Plywood
g) Nails
h) Jute

3.2.2 Apparatus & Machineries

i. Bar cutter machine
ii. Concrete vibrator
iii. Slump test apparatus
iv. Concrete moulds
v. Concrete mixer
vi. Compression testing
vii. Supports for the two-way slab.
viii. Curing pond

3.3 POLYPROPYLENE FIBRE

3.3.1 Historical Use of Fibres

The use of fibres in brittle matrix materials has a long history going back at least 3500 years when sun-baked bricks reinforced with straw were used to build the 57 m high hill of Aqar Quf near Baghdad (Newman et al, 2003).

In western history, the oldest recorded account of the use of fibre reinforcement is in the Old Testment of the Bible, Exodus 5:6-7:

> And Pharaoh commanded the same day the taskmasters of the people, and their officers, saying, 'Ye shall no more give the people straw to make brick, as heretofore: let them go and gather straw for themselves.' (Mary S. J. Gani, 1997).

In a recent time, about 100 years ago, the asbestos fibres have been invented and used to reinforced cement products. However, primarily due to health hazards associated with asbestos fibres, alternate fibre types, steel, polypropylene and glass fibres, were introduced for the same purpose throughout the 1960s and 1970s. Besides that, cellulose fibres were also being used for at least 50 years.

3.3.2 Polypropylene Fibre

Polypropylene Fibre are synthetic fibres having isotactic configuration and circular cross-section (R. N. Swamy, 1992). It is available in two forms, monofilaments fibres and fibrillated fibres.

3.3.2.1 Monofilaments fibres

Monofilaments fibres are manufactured from extruded sheet/film material which is subjected to molecular alignment, coated and cut to appropriate length (John Knapton, 1999). Monofilaments fibres are finer and a smoother surface can be produced from the use of monofilaments fibres compared to film fibres.

3.3.2.2 Fibrillated Fibres

Fibrillated fibres are manufactured from extruded sheet/film material which is subjected to molecular alignment, fibrillated, coated and cut to appropriate length (John Knapton, 1999). Clustering of fibres is overcome by the mixing of aggregates in the concrete mix. Basic properties of fibrillated fibres are:

- Density = 900 kg/m^3
- Tensile strength range = 560 – 700 N/mm^2
- Elastic modulus = 3.5 kN/mm^2
- Melting point = 160 – 170 °C.

Fibrillated fibres have a rough surface texture which gives each fibre a high degree of mechanical bond to the concrete (John Knapton, 1999).

3.3.3 Fibre Reinforced Concrete

Concrete made by Ordinary Portland Cement (OPC) is relatively brittle. If it is experience tension forces or tensile stress, the non-reinforced concrete could crack easily. In order to solve the problem, since mid 1800's, the use of steel reinforcement is invented to resist the tensile stress to prevent the crack of structural failure from occurring (R. Brown, A. Shukla and K.R. Natarajan, 2002).

However, another issue has occurred due to the use of steel reinforcement which is the corrosion or rust of the steel. Steel has low resistance towards the effect of corrosion. It is due to the chemical reaction of iron ion and the oxidants. When the iron ions are having contact with water, air or any other strong oxidants or/and acid and salts, it will rust. Rust has a volume between four to ten times the iron, which dissolves to form it. The volume expansion produces large tensile stresses in the concrete, which initiates cracks and results in concrete spalling from the surface.