FLEXURAL BEHAVIOR OF PERMANENT PRECAST FORMWORK BEAMS

NURULSIQQIN AISHAH BT MD YUSUF

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Specially dedicated to my beloved

Family and friends

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ABSTRACT

This study is to explore the flexural behaviour of permanent precast formwork beam. The total three beams that have dimensions 150 mm x 300 mm x 3000 mm have been casted and tested. Two beams are permanent precast formwork beam and one beam as a control beam. The beam have been tested using America Society Testing and Material (ASTM) C78 for testing flexural strength of concrete beams using a four point bend test by the third-point method. The results show that the permanent precast formwork beams exhibit increased flexural strength and higher bending capacity compared to normal concrete beam.

ABSTRAK

Kajian ini adalah untuk mengkaji kelakuan lenturan rasuk acuan kekal pratuang. Tiga rasuk sebagai spesimen yang mempunyai dimensi 150 mm x 300 mm x 3000 mm telah diuji. Dua rasuk pratuang adalah rasuk acuan kekal dan satu rasuk sebagai rasuk kawalan. Rasuk telah diuji menggunakan America Society Testing and Material (ASTM) C78 untuk menguji kekuatan lenturan rasuk konkrit menggunakan kaedah ujian empat titik dengan kaedah tiga titik. Keputusan menunjukkan bahawa rasuk pratuang acuan tetap menunjukkan peningkatan kekuatan lenturan dan keupayaan lenturan yang lebih tinggi berbanding dengan rasuk konkrit biasa.

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LIST OF SYMBOLS

A_s	-	Area of tension reinforcement
a_v	-	Shear span
b	-	Width of beam
b_v	-	Width of beam, to be taken as b for a rectangular beam
d	-	Effective depth
E	-	Elastic modulus
E_s	-	Modulus of elasticity of steel
ε_o	-	Concrete strain when peak stress is reached
ε_{cu}	-	Ultimate concrete strain at compression = 0.0035
ε_y	-	Design yield strain
F_{cc}	-	The resultant compressive force in the concrete
F_{st}	-	The resultant tensile force in the reinforcing steel
f_{cu}	-	Characteristic strength of concrete
f_y	-	Characteristic strength of reinforcement
h	-	Overall depth of beam
M	-	Bending moment
s_v	-	Longitudinal spacing of link reinforcement
V	-	Shear force
v	-	Design shear stress
v_c	-	Design shear stress for concrete
x	-	Neutral axis depth
γ_s	-	surface energy
Φ	-	Curvature

LIST OF EQUATIONS

CHAPTER 1

INTRODUCTION

1.1 Introduction

Formworks as temporary structures are an important elements of the overall construction plan. A temporary structure in construction affects the safety of the workers on the job and the general public and there is also the relationship of the temporary structure to the finished structure.

Temporary structures are sometimes incorporated into the finished work or are removed at the end of the conclusion of their usefulness. In either case, the contractor will have to deal with supervision work, code requirements, contract and legal requirements, and perhaps disputes with others over the work being performed. As far as design, drawings and specifications are concerned, they depend on the temporary structure under consideration.

In the new era of construction, a more efficient and advantageous type of formwork is widely used by growing numbers of contractors, which is the permanent precast formwork. Permanent precast formworks have been widely used in nowadays construction because it can develop innovative, it is more economical, and more efficient method in construction compared to the usage of temporary formwork. By using a permanent precast formwork, the construction of building can be more efficient; the speed of the construction can be increased as well as the cost of the construction, and can also reduce the manpower needed at the construction site.

Figure 1.1 Sample of permanent precast formwork

1.2 Background of Study

Formwork development has paralleled the growth of concrete construction throughout the 20th century. The increasing acceptance of concrete as a major construction material presents the form builder a new range of problems in the development of appropriate sheathing materials and maintenance of rigid tolerances.

Formwork is a mould including all supporting structures, used to shape and support the concrete until it attains sufficient strength to carry its own weight. It should be capable of carrying all imposed dead and live loads apart from its own weight.

There are some requirements of a good formwork system, which are:

i. The way the formwork can be erected and de-shuttered fast

.

ii. The good concrete quality and surface finish can be achieved.

iii. The optimum stock of formwork required for the size of work force, the specified time schedule and flow of materials.

iv. The overall cost savings that can be achieved using the right type of formwork.

v. The safety that can be improved for the site personnel.

In order to successfully carry out its function, formwork must achieve a balance of following requirements such as containment, strength, resistance to leakage, accuracy, ease of handling, access for concerted and economy.

Containment of formwork mean formwork must be capable of shaping and supporting the fluid concrete until it cures. Strength of formwork must be capable of safely withstanding without distortion or danger the dead weight of the fluid concrete is placed on it, labour weight, equipment weight and any environmental loadings.

Resistance to leakage for formwork can be defined with all joints in formwork must be either close fitting of covered with form tape to make them grout tight. If grout leakage occurs the concrete will leak at that point. Leakages cause honeycombing of the surface. Formwork must be accurately set out so that the resulting concrete product is in a right place and is of correct shape and dimensions.

The formwork must be easy to handle which form panels and units should be designed so that their maximum size does not exceed that which can be easily handled by hand or mechanical means. In addition all formwork must also be designed and constructed to include facilities for adjustments, levelling, easing and striking without damage to the form work or concrete.

Any formwork arrangement should provide access for placing of the concrete. The extent of this provision will be depending on the ease of carrying out the concrete operations.

The cost of formwork is very expensive. On average about 35% of the total cost of any finished concrete unit or element can be attributed to its formwork, out of this just over 40% can be taken for material for formwork and 60% for labour. The formwork designer must therefore not only consider the maximum number of times that any form can be reused, but also produce a design that will minimize the time taken for erection and striking.

Traditionally, formwork requirements have been left to the construction stage and the main contractor's temporary works designer, but this can lead to significant loss of benefit unless the permanent works designer provides appropriate guidance. Permanent formwork in construction defines the terminology relating to permanent formwork, identifies where the responsibilities lie for its design and safe use and outlines the regulations governing its use.

This study is all about of the application of permanent precast formwork beam that can develop innovative, economical and efficient methods of construction in reducing the application of temporary formwork. There are many advantages of using permanent precast formwork beam such as:

i. The construction of building more efficient.

ii. It can increase the speed of construction time and reduce money.

iii. The construction site is cleaner.

iv. It also can reduce the manpower at construction site improved safety and economy of construction,

v. Long-term durability, appearance and reduced maintenance costs in civil engineering applications.

According to Kamran (2007), formwork can be defined as a structure, usually temporary, but in some cases wholly or partly permanent used to contain poured concrete to mould it to the required dimensions and support it until it is able to support itself. It consists primarily of the face contact material and the bearers that directly support the face contact material.

Permanent formwork can be classified into two groups which participating and non-participating (Design Manual for Roads and Bridges, 1991).

i. Participating formwork

Precast concrete units incorporating a welded lattice projecting into and providing shear connection with the overlying insitu concrete deck to form a composite deck slab. This is the only type of participating permanent formwork which has been used in bridges in recent years.

ii. Non-participating formwork

a. Glass fibre reinforced cement (GRC) consisting of hydraulic mortars reinforced with alkali resistant glass is manufactured to give a range of sections designed to support various deck slab thicknesses and spans. Single skin panels, either flat sheet or corrugated, where the in-situ concrete is in contact with the GRC over the full surface area of the panel, are acceptable for use. The use of polystyrene formers in the corrugations is not permitted.

b. Profiled steel sheeting (PSS) is usually of the order of 1mm thick and is protected by galvanising with an additional polyester coating. This material has not been widely used, but in a few instances corrosion to untreated cut edges and site damage to the coatings has been observed, although this has not seriously impaired the structural performance. PSS should not contain indentations which may form a shear connection with the in situ concrete, since there is a risk of fatigue cracking initiating from this detail.

c. Glass reinforced plastic (GRP) is a flat laminated panel consisting of a resin mortar filling between two thin sheets of glass reinforced plastic. One surface of the panel has projecting steel reinforcing ribs on edge encased within the GRP. Generally these have performed satisfactorily although there have been isolated cases of corrosion of the steel ribs. This was due to incomplete covering by GRP material and was exacerbated by poor storage conditions of the steel prior to manufacturing the panels. Properly manufactured panels should not suffer from this problem. GRP formwork should only be used with the ribs projecting into the in-situ concrete deck slab. There should be no filler materials such as expanded polystyrene placed between the ribs, which would prevent full contact between the deck concrete and the surface of the ribbed panels.

In this study, there are two types of permanent precast formwork beam that were used which are glass fibre reinforced concrete and glass fibre reinforced concrete with wire mesh. Besides that, normal beam is used to be a control beam. The study is carried out to investigate the differences of flexural behaviour precast permanent formwork beam with normal beam.

Glass fibre Reinforced Concrete (GRC) has been extensively used as permanent formwork for the past twenty years, corrugated or flat to suit all supporting beam design.

GRC formwork has excellent performance characteristics and its inherent material properties provide the specified and contractor with a permanent surface skin to the bridge deck concrete which:

i. Has a thin cross section, yet provides durability and steel protection equal to much thicker concrete cover.

ii. has a high resistance to fire and will not emit toxic fumes

iii. Eliminates spalling of exposed faces.

iv. Provides flexibility for pouring sequences and concreting schedules, which can reduce construction time.

v. Enables the final appearance of the deck structure to be assessed on-site before concrete is poured.

The GRC shall be the following properties on completion of cure. The dry density of the GRC should not be less than 1700 kg/m^3

Table 1.1 Properties of glass fibre reinforced concrete.

Compressive Strength (tested to ASTM : C 109/C 109M : 2002)	
Maximum Load	53269.7 N
Compressive Strength	21.31 N/mm²
Flexural Strength (tested to ASTM : C 580 – 98)	
Flexural Strength	33.8 N/mm²
Modulus of Elasticity	6172.8 MPa
Charpy Impact Strength (tested to ASTM	10.5 µm/mºC
Coefficient of Thermal Expansion (tested to ASTM E831 : 2000)	10.5 µm/mºC
Thermal Conductivity (tested to ASTM C518 : 1991)	0.12258 w/mºK

1.3 Problem Statement

Generally, conventional formwork is widely used in the construction in Malaysia because of its flexibility and easy to produce. The most common material for conventional formwork is timber and plywood. Traditional Timber formwork is widely used in the construction in Malaysia because of its flexibility and easy to produce. Traditional timber formwork is built on site out of timber and plywood or moisture-resistant particleboard. Although it is easy to produce, the time-consuming for larger structures to be built is longer, and the plywood facing has a relatively short lifespan. The formwork which is made of wood or timber may have to be replaced after a few uses.

Figure 1.2 The view of site construction that uses traditional timber formwork.

As compared to traditional timber formwork, permanent precast formwork is manufactured at factory. The main advantages of this permanent precast formwork is reducing the traditional site based trades like traditional timber formwork, brickwork, and plastering and thus enabling the contractors to reduce the overall labour content in the building construction. By using permanent precast formwork, the use of wood formwork can be reduced. It is also can develop the economical method of construction. However, it is still used extensively where the labour costs are lower than the costs for procuring reusable formwork. Moreover, the unskilled labourer can be easily trained to construct building using the permanent precast formwork and provide faster construction and cost saving.

1.4 Objectives of Study

The objectives of this case study are:

i. To obtain an optimum content of glass fibre in glass fibre mortar mix design.

ii. To investigate the flexural behaviour and bending capacity of permanent precast formwork beams.

1.5 Scope of Study

This study is mainly focused on the testing of concrete beams with different types of permanent precast formwork under the four point bend test. Design calculation and laboratory work were carried out accordingly to achieve the objectives of this study.

This study was conducted in the Material and Structure Laboratory. In the laboratory work, three beams were casted and tested using the same grade of concrete, steel bars reinforcement, and testing method. The results of this study are used to determine the flexural behaviour of the beam and which types of formwork have higher bending capacity under the four point bend test.

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