UNIVERSITI PUTRA MALAYSIA

# *COMPARATIVE STUDY ON STRUCTURAL BEHAVIOUR OF BONDED AND UNBONDED POST-TENSIONED BEAM*

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**BY**

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*Dedicated to my Family*

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## ABSTRACT

In this study, a simple computer program are written using FOTRAN 90 to investigate the behavior of simply supported beam constructed with straight tendon which are subjected to three different load cases. Considering the same stresses applied, beam subjected to loading at one third span shows a less deflection than other load cases. Behavior due to the deflection of bonded tendon gave good performance than unbonded tendon. However, beams with larger span-to-depth ratio would require deviators in case of external prestressing beam to achieve the desired performance. Parabolic and trapezoidal tendon allows the prestressed beam to carry heavier loads because of the balancing effects of the vertical component of the prestressing nonstraight tendon. Hence it will reduce the required prestressing force at the mid span than the force required in the straight tendon.

**ABSTRAK**

Dalam kajian ini, satu program telah ditulis menggunakan FORTRAN 90 untuk mengkaji kelakuan rasuk prategasan yang ditindaki dengan tiga bentuk beban. Rasuk prategasan yang dikenakan tegasan yang sama akan menunjukkan pengurangan kelakuan lenturan jika dikenakan beban pada satu pertiga rasuk. Kelakuan berkaitan lenturan bagi rasuk prategasan terikat adalah lebih baik berbanding kelakuan lenturan bagi rasuk prategasan tidak terikat. Bagaimanapun, bagi rentang yang mempunyai nisbah L/d melebihi 20, akan memerlukan penyokong pada titik-titik tertentu rentang untuk menghasilkan kelakuan yang lebih baik. Beban yang lebih besar dapat dikenakan terhadap rasuk prategasan yang menggunakan keluli prategasan yang berbentuk parabola, trapezium atau bersudut disebabkan kesan kestabilan pugak. Maka, ia dapat mengurangkan tegasan keluli prategasan yang diperlukan pada tengah rentang berbanding keluli prategasan yang lurus.

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# APPROVAL FORM

The project attached hereto entitled, **"Comparative Study on Structural Behaviour of Bonded and Unbonded Post-Tensioned Beam"** prepared and submitted by Nurazuwa binti Md Noor in partial fulfillment of the requirements for the Degree of Master of Science in Structural Engineering and Construction is hereby approved.

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# CHAPTER I

# INTRODUCTION

## 1.0 General

Post-tensioning is a method of reinforcing and prestressing concrete, masonry and other structural elements. Simply, concrete and masonry are very strong in compression but relatively weak in tension. In comparison, steel is very strong in tension. Combining steel with concrete or masonry therefore results in a product that can resist both compressive and tensile forces. Further, if concrete is pre-stressed or "squeezed together" with the help of the steel (known as prestressing steel) during the construction phase, its resistance to cracking increases significantly.

External prestressing is a special technique where the first applications date back to more than 60 years. As early as in 1936, low strength prestressing steel is used as external tendons for Aue-bridge in Saxony, Germany which was designed by F. Dischinger before the Second World War [1]. However, during the succeeding years of external prestressing, the advantageous characteristics with internal bonded tendon were discovered. This brings to the 'silent' condition of external prestressing but it did not disappear completely. External prestressing is defined as an arrangement of prestressing tendons outside the section being stressed. The forces are transferred at the anchorage blocks or deviators and those external tendons may be straight or deviated at different points in order to follow the bending moments (see Figure1.1). Whereas, internal prestressing is defined as tendon arrangement within the cross-section of the structures. Internal prestressing can be bonded between the structure and grouted ducts or unbonded between the ducts and tendons.

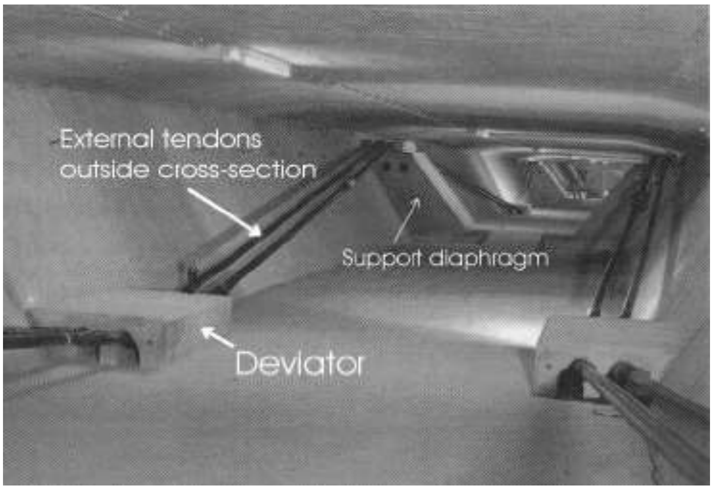


Figure 1.1: Box girder bridge with externally deflected tendons (mysite.wanadoo-members.co.uk/jens/thesis/1_externalPrestress.pdf, 2001)

There are two methods of prestressing: pre-tensioning and post-tensioning [2]. Pre-tensioning, the prestressing steel is stressed at a precast manufacturing facility. Pre-tensioning a concrete member is accomplished by tensioning prestressing strands to the required tensile stress using external jacks and anchors, casting the concrete member around the tensioned strands and, releasing the external strand anchors after the concrete has achieved the required minimum strength.

Precompression is induced by the transfer of force through the bond between the prestressing strands and concrete.

With unbonded post-tensioning, the prestressing steel is installed on the job site just before concrete is poured. The prestressing steel is greased and encased in an extruded plastic sheathing to prevent it from bonding to the concrete (Figure 1.2). After the concrete hardens, the prestressing steel is gripped at both ends strands using an external jack, tensioned and anchored to pre-stress the concrete. The strands are typically internal to the member, and may be placed externally. A second anchor is secured against the member and the jacking force is released to transfer the load into the member as a precompression force.

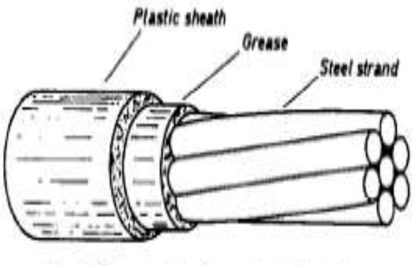


Figure 1.2: Component of an unbonded tendon

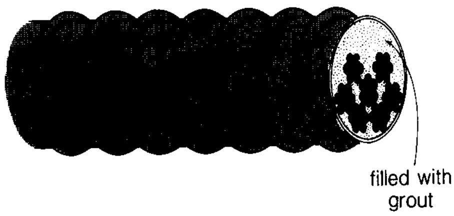


Figure 1.3: Component of an bonded tendon

The completed assembly of steel, sheathing and anchors is known as a tendon. Unbonded tendons generally consist of a single strand. With bonded post-tensioning, the prestressing steel is placed in a corrugated metal or plastic duct that has been cast into the concrete. The prestressing steel is usually placed after the concrete has been placed. A bonded post-tensioned tendon typically contains more than one prestressing steel strand and can range from several strands to 55 or more strands in a single tendon, while the anchorage assembly consists of confinement reinforcing steel, bearing plate, anchor head, wedges, and grout cap. The strands can be stressed individually or simultaneously with a monostrand or multistrand hydraulic jack. After stressing, the duct is filled with a low-shrinkage, low-bleed flowable cementitious grout to achieve bond to the concrete member and to protect the prestressing steel from corrosion.

Today, post-tensioning is used for a wide range of applications including office buildings, condominiums, hotels, parking structures, slab-on-ground foundations, ground anchors, storage tanks, stadiums, silos, and bridges. Other applications include post-tensioning in pavement, masonry, bridge decks, seismic walls, and single-family homes [3]. It also can be effectively combined with other structural materials and has been used to strengthen steel, reinforced concrete, masonry, and timber structures, as well as enhance and extend the capabilities of precast, pre-tensioned elements. Examples include spliced precast bridge girders, segmental bridges and hybrid precast moment resisting frame buildings.

One of the most significant reasons for its growth is that post-tensioning allows designers to achieve longer spans with shallower concrete sections, providing owners with the economical advantage of lower floor-to-floor height. This allows architects and engineers to design and build lighter and shallower concrete structures without sacrificing strength. Other key benefits of post-tensioning include functional flexibility, improved deflection and vibration control, crack control and reduced maintenance.

## 1.1 Problem of Study

Nowadays, prestressing are widely used in the new construction technologies, structures strengthening and repairing. However, due to growing demand for prestressed structures in worldwide including Malaysia, research and laboratory test are progressively continuing. Although various advantages of prestressing have been reported, some question concerning the behavior of bonded and unbonded prestressed concrete structure at ultimate are often arisen in the design practice. This shows that there are still problems in understanding the behavior of prestressed structures especially on unbonded tendon both internally or externally tendon.

An analysis on simply supported beam has been done by Mitchell and Collins in 1990 based on experimental work carried out in 1972 to study the behavior of unbonded straight tendon subjected to load at two third span. Due to these findings, an attractive alternative will be carried out using FORTRAN programming to study the behavior of bonded and unbonded prestressed beam subjected to one point load and uniform distributed load. Based on this analysis, the behavior of prestressed beam subjected to three different load types will be analyses and compare. Additionally, the behavior of different cable profile is also conducted in this analysis.

## 1.2 Objective of Study

Objective of the study are to:

i. Study the existing theoretical and empirical method of analysis of bonded and unbonded prestressing beam.
ii. Determine the limitation of the methods.
iii. Compare the behaviour of bonded and unbonded prestressed beams, having different cable profile, and load patterns between empirical and theoretical methods.

## 1.3 Scope of Study

A study on the existing empirical method of bonded and unbonded prestressing beam by previous researchers will be discussed in literature review hence determine the limitation of those methods. The next section deals with the analysis. Analysis will be carried out using suitable software to perform a bonded and unbonded prestressed programmed. Theoretical process is based on the procedure of total strain compatibility method as described by Collins and Mitchell [4]. The scope of this study is limited to:

i. Rectangular of post-tensioning simply supported prestressed beams at ultimate limit state.

ii. Beams with different load path.

iii. Beams with different cable profile.

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