A Laboratory Manual for

Design of Prestressed Concrete Structures

(3170624/2970611)

B.E. Semester 7 (Civil)

Shantilal Shah
Engineering College

Directorate of Technical Education
Gandhinagar, Gujarat

Institute Name

Certificate

This is to certify that Mr./Ms. ___________________________________ ________ Enrollment No. _______________ of B.E. Semester _____Civil Engineering of this Institute (GTU Code: 043) has satisfactorily completed the Practical / Tutorial work for the subject Design of Prestressed Concrete Structures (3170624) for the academic year 2022-23.

Place: __________

Date: __________

Name and Sign of Faculty member

Head of the Department

Preface

The basic aim of laboratory/practical/field work is to enhance the required skills as well as creating ability amongst students to solve real time problem by developing relevant competencies in psychomotor domain. By keeping this in view, GTU has designed competency focused outcome-based curriculum for engineering degree programs where sufficient focus is given to the practical work. It shows importance of enhancement of skills amongst the students and pays attention to utilize every second of time allotted for practical amongst students, instructors and faculty members to achieve relevant outcomes by performing the experiments rather than having merely study type experiments. It is must for effective implementation of competency focused outcome-based curriculum that every practical is keenly designed to serve as a tool to develop and enhance relevant competency required by the various industry among every student. These psychomotor skills are very difficult to develop through traditional chalk and board content delivery method in the classroom. Accordingly, this lab manual is designed to focus on the industry defined relevant outcomes, rather than old practice of conducting practical to prove concept and theory.

By using this lab manual students can go through the relevant theory and procedure in advance before the actual performance which creates interest and students can have basic idea prior to performance. This in turn enhances pre-determined outcomes amongst students. Each experiment in this manual begins with competency, industry relevant skills, course outcomes as well as practical outcomes (objectives). The students will also achieve safety and necessary precautions to be taken while performing practical.

This manual also provides guidelines to faculty members to facilitate student centric lab activities through each experiment by arranging and managing necessary resources in order that the students follow the procedures with required safety and necessary precautions to achieve the outcomes. It also gives an idea that how students will be assessed by providing rubrics.

This course is an elementary course on Design of Prestressed Concrete Structures. The course is specifically aim to familiarize with the basic concepts of prestressing and to develop understanding of various design philosophies, Indian Standard Codal provisions for the design of statically determinate Prestressed Concrete elements.

Utmost care has been taken while preparing this lab manual however always there are chances of improvement. Therefore, we welcome constructive suggestions for improvement and removal of errors if any.

Practical – Course Outcome matrix

Course Outcomes (COs):

CO1 : Apply the basic concepts of prestressing in various Civil Engineering Structures.

CO2 : Assess the various prestressing losses in prestressed concrete elements as per Indian Standard Codal provisions

CO3 : Analyse and design statically determinate prestressed concrete flexural elements and draught prestressing details

CO4 : Analyse and design the prestressed concrete elements for Shear and Torsion and draught detailing

CO5 : Analyze and design Prestressed Compression and Tension Members and draught prestressing details

Sr. No.	Objective(s) of Assignment	CO 1	CO 2	CO 3	CO 4	CO 5
1.	**To learn various principals of prestressing.**	√				
2.	**To calculate different losses in prestressing.**		√			
3.	**To learn flexural design of prestressed concrete elements.**			√		
4.	**To understand various aspects of shear and torsional strength Design**				√	
5.	**To solve problems related to prestressed compression and tension members**					√

Industry Relevant Skills

The following industry relevant competencies are expected to be developed in the student by undertaking the practical work of this laboratory.

1. Problem-solving
2. Team-work

Guidelines for the Faculty members

1. Teacher should provide the guideline with demonstration of practical to the students with all features.
2. Teacher shall explain basic concepts/theory related to the experiment to the students before starting of each practical.
3. Involve all the students in performance of each experiment.
4. Teacher is expected to share the skills and competencies to be developed in the students and ensure that the respective skills and competencies are developed in the students after the completion of the experimentation.
5. Teachers should give opportunity to students for hands-on experience after the demonstration.
6. Teacher may provide additional knowledge and skills to the students even though not covered in the manual but are expected from the students by concerned industry.
7. Give practical assignment and assess the performance of students based on task assigned to check whether it is as per the instructions or not.
8. Teacher is expected to refer complete curriculum of the course and follow the guidelines for implementation.

Instructions for Students

1. Students are expected to carefully listen to all the theory classes delivered by the faculty members and understand the COs, content of the course, teaching and examination scheme, skill set to be developed etc.
2. Students shall organize the work in the group and make record of all observations.
3. Students shall develop maintenance skill as expected by industries.
4. Student shall attempt to develop related hand-on skills and build confidence.
5. Student shall develop the habits of evolving more ideas, innovations, skills etc. apart from those included in scope of manual.
6. Student shall refer technical magazines and data books.
7. Student should develop a habit of submitting the experimentation work as per the schedule and s/he should be well prepared for the same.

Common Safety Instructions

1. Students are expected to carefully listen and follow the instructions given by the faculty.
2. Students are expected to carefully read and follow the safety instructions displayed in the laboratory.

Laboratory Report Grading Rubrics

Sr. No.	Rubrics	Exceeds expectation (2 marks)	Meets expectation (1 mark)	Doesn't meet expectation (0 mark)
1.	Understanding and solving assignment Problem.	✓ Student has understood and solved the main problem. ✓ Student has correctly written the assignment problem and solution.	✓ Student needed guidance to understand the solution of main problem. ✓ Student needs help to solve the problem correctly.	✓ Student was unable to understand the main problem. ✓ Student was unable to solve the problem correctly.
2.	Conduction of Experiment (Software)	✓ Student has full command on the basic tools of the software. ✓ Has applied all the steps in correct sequence to obtain the results.	✓ Student has limited command on the basic tools of the software. ✓ Some steps are followed but not in proper sequence.	✓ Student has no idea how to use the basic tools of the software. ✓ Student has no idea regarding the steps to be followed to obtain the results.
3.	Team work	✓ Student has performed the duties assigned and actively assisted others.	✓ Student has shown limited performance in the duties that are assigned.	✓ Student has not performed any duties of assigned team role.
4.	Neatness	✓ Very neat and well organized headings, statements and calculation placed properly.	✓ Somewhat neat with some effort and care taken in its preparation.	✓ Messy writing with statements placed haphazardly, which seems to support little effort or care taken in its preparation.
5.	Punctuality	✓ Student was on time and submitted the assigned work on time.	✓ Student was on time but not submitted assigned work on time.	✓ Student was not on time and not submitted the assigned work.

Index

(Progressive Assessment Sheet)

Sr. No.	Objective(s) of Assignment	Page No.	Date of performance	Date of submission	Assessment Marks	Sign. of Teacher with date	Remarks
1	Introduction						
2	Losses in Prestress						
3	Flexural Design of Prestressed Concrete Elements						
4	Shear and Torsional strength Design						
5	Prestressed Compression and Tension Members						
Total							

ASSIGNMENT - 1

Introduction

1.1 Explain basic concepts of prestressing.

1.2 Briefly describe historical development of prestressed concrete structures.

1.3 What is basic need of using high strength steel and concrete in prestressed concrete structures?

1.4 Write advantages and limitations of using prestressed concrete.

1.5 Explain types of prestressing systems.

1.6 Explain load balancing concept.

1.7 A rectangular concrete beam, 100 mm wide by 250 mm deep, spanning over 12m is prestressed by a straight cable carrying an effective prestressing force of 300 kN located at an eccentricity of 40 mm. The beam supports a live load of 2.5 kN/m. Take density of concrete equal to 25 kN/m^3.

a. Calculate and draw the resultant stress distribution for the central cross section of the beam.

b. Find the magnitude of the prestressing force with an eccentricity of 40 mm which can balance the stresses due to dead and live loads at the bottom fiber of the central section of the beam.

1.8 A prestressed concrete beam supports a live load of 5 kN/m over a simply supported span of 12m. The beam has an I-section with an overall depth of 600mm.The thickness of the flange and web are 100 and 120 mm respectively. The width of the flange is 250 mm. The beam is to be prestressed by an effective prestressing force of 350 kN at a suitable eccentricity such that the resultant stress at the soffit of the beam at the centre of span is zero.

a. Find the eccentricity

b. If the tendon is concentric, what should be the magnitude of prestressing force for the resultant stress to be zero at the bottom fiber of the central span section?

c. Verify your results using any professional structural analysis software.

Rubrics	**1**	**2**	**3**	**4**	**5**	**Total**
Marks						

ASSIGNMENT - 2

Losses in Prestress

2.1 Explain in detail various types of losses in pre-tensioned and post-tensioned prestressed concrete.

2.2 A post-tensioned cable of a 10 m long beam is initially tensioned to a stress of 1000 N/mm^2 from one end. If the tendons are curved so that the slope is 1 in 15 at each end with an area of 750 mm^2, calculate the loss of prestress due to friction, for the following data:
Coefficient of friction between duct and cable = 0.55
Friction coefficient for wave effect = 0.0015/m
During anchoring, if there is a slip of 3 mm at the jacking end, calculate the final force in the cable and the percentage loss of prestress due to friction and slip.

2.3 A pre-tensioned beam 250 mm wide and 350 mm deep is prestressed by 12 wires each of 7 mm diameter initially stressed to 1200 N/mm^2 with their centroids located 100 mm from the soffit. Estimate the final percentage loss of stress due to elastic deformation, and relaxation as per IS: 1343-2012 provisions:
Relaxation of steel stress = 90 N/mm^2
E_s = 210 kN/mm^2 , E_c = 35 kN/mm^2

2.5 A concrete beam is prestressed by a cable with an initial stress of 1200 N/mm^2 in the wires. The grade of concrete in the beam is M-50. The beam is located in an area having a relative humidity of 50 per cent. The beam is exposed to the environment on three sides having a depth of 300 m and a width of 200 mm. The beam was cured for seven days before it was prestressed. Using the Indian Standard Code method, estimate the loss of stress in steel due to shrinkage of concrete at the age of (a) 28 days and (b) 60 years. Assume modulus of elasticity of steel as 200 kN/mm^2.

2.6 A concrete beam of rectangular section 150 mm wide and 350 mm deep is prestressed by five wires of 7 mm diameter located at an eccentricity of 50 mm, the initial stress in the wires being 1100 N/mm^2 . Estimate the final loss of stress in steel due to creep of concrete according to the Indian Standard Code method (IS: 1343-2012).

Rubrics	1	2	3	4	5	Total
Marks						

ASSIGNMENT - 3

Flexural Design of Prestressed Concrete Elements

3.1 Describe different modes of failure of prestressed concrete elements in flexure.

3.2 Explain strain compatibility method for determination of flexural strength of prestressed concrete.

3.3 A pretensioned concrete beam with a rectangular section 150 mm wide and 200 mm deep, is prestressed by 10 high tensile wires of 2.5 mm-diameter located at an eccentricity of 40 mm. The initial force in each wire is 7.5 kN The strain loss in wires due to elastic shortening, creep and shrinkage of concrete is estimated to be 0.0012 units. The characteristic cube strength of concrete is 40 N/mm^2 . Use the standard load-strain curve of 2.5 mm-diameter steel wire , estimate the ultimate flexural strength of the section using the strain compatibility method.

3.4 A pretensioned prestressed concrete beam having a rectangular section with a width of 200 mm and overall depth of 400 mm is prestressed by tendons of effective area 520 mm^2 at an effective depth of 350 mm. Assuming the characteristic strength of concrete and steel as 40 and 1600 N/mm^2 , estimate the ultimate flexural strength of the section using the provisions of the Indian Standard Code.

3.5 A precast pretensioned T-beam has a flange width of 1100 mm and thickness of 150 mm. The width and depth of the rib are 250 and 1400 mm, respectively. The high tensile steel tendons of cross-sectional area 4500 mm^2 are located at an effective depth of 1480 mm. If the characteristic strength of concrete and steel are 40 and 1600 N/mm^2 , respectively, calculate the flexural strength of the T-section using Indian Standard Code provisions.

3.6 A post-tensioned bridge girder with bonded tendons is of box section having overall dimensions 1100 mm wide and 1600 mm deep, with wall thickness of 150 mm. The high tensile steel located at an effective depth of 1500 mm has a cross-sectional area of 4000 mm^2 If the characteristic strength of concrete and steel are 40 and 1600 N/mm^2 , respectively, estimate the flexural strength of the box girder using Indian Standard Code specifications

3.7 A prestressed concrete beam of rectangular section 150 mm wide and 350 mm deep, spans over 6 m. The beam is prestressed by a straight cable carrying an effective force of 220 kN at an eccentricity of 50 mm. The modulus of elasticity of concrete is 38 kN/m^2 . Compute the deflection at center of span for the following cases: (a) Deflection under (prestress + self-weight) (b) Find the magnitude of the uniformly distributed live load which will nullify the deflection due to prestress and self-weight.

3.8 The end block of a post-tensioned prestressed member is 550 mm wide and 550 mm deep. Four cables, each made up of seven wires of 12 mm-diameter strands and carrying a force of 1100 kN, are anchored by plate anchorages, 150 mm by 150 mm, located with their centers at 125 mm from the edges of the end block. The cable duct is of 50 mm diameter. The 28-day cube strength of concrete fcu is 40 N/mm^2 . The cube strength of concrete at transfer fci, is 30 N/mm^2 . Permissible bearing stresses behind anchorages should conform with IS: 1343. The characteristic yield stress in mild steel anchorage reinforcement is 260 N/mm^2 . Design suitable anchorages for the end block.

3.9 Design a pretensioned roof purlin to suit the following data:

Effective span = 7 m Applied load = 4 kN/m Load factors For dead load = 1.4 For live load = 1.6 Concrete cube strength, f_{cu} = 45 N/mm^2 Cube strength at transfer, fci = 30 N/mm^2 Tensile strength of concrete, f_t = 1.7 N/mm^2 Modulus of elasticity of concrete, E_c = 34 kN/mm^2 Loss ratio, h = 0.8 Permissible stresses At transfer: Compressive stress, f_{ct} = 15 N/mm^2 Tensile stress, f_{tt} = –1 N/mm^2 At working load: Compressive stress, f_{cw} = 17 N/mm^2 Tensile stress, f_{tw} = 0, 7 mm high-tensile steel wires having an ultimate tensile strength, f_{pu} = 1500 N/mm^2 are available for use. Verify your results using any professional structural analysis software.

3.10 Design a post-tensioned roof girder to suit the following data:

Effective span = 28 m Live load = 10 kN/m Dead load (excluding self-weight) = 2 kN/m Load factors for dead load = 1.4, for live load = 1.6, Cube strength of concrete, f_{cu} = 50 N/mm^2 Cube strength at transfer, f_{ci} = 40 N/mm^2 Tensile strength of concrete, f_t = 1.7 N/mm^2 Modulus of elasticity of concrete, E_c = 34 kN/mm^2 ,Loss ratio h = 0.85, 8 mm diameter high-tensile wires having a characteristic tensile strength f_{pu} = 1600 N/mm^2 are available for use. The modulus of elasticity of high tensile wires is 200 kN/mm^2 . Design the beam as per Indian standard code IS: 1343 recommendations. Verify your results using any professional structural analysis software.

3.11 A precast pretensioned beam of rectangular section has a breadth of 150 mm and a depth of 250 mm. The beam with an effective span of 5 m, is prestressed by tendons with their centroids coinciding with the bottom kern. The initial force in the tendons is 200 kN. The loss of prestress may be assumed to be 15 per cent. The beam is incorporated in a composite T-beam by casting a top flange of breadth 400 mm and thickness 50 mm. If the composite beam supports a live load of 6 kN/m^2 , calculate the resultant stresses developed in the precast concrete assuming the pretensioned beam as unpropped.

3.12 A highway bridge deck slab spanning 12 m is to be designed as a one way prestressed concrete slab with parallel post-tensioned cables carrying an effective force of 500 kN. The deck slab is required to support a uniformly distributed live load of 25 kN/m^2 . The permissible stresses in concrete should not exceed 15 N/mm^2 in compression and no tension is permitted at any stage. Design the spacing of the cables and their position at mid-span section. Assume loss of prestress as 18 per cent.

3.13 Design a post-tensioned prestressed concrete two-way slab, 5 m by 8 m, with discontinuous edges, to support an imposed load of 2.5 kN/m^2 . Cables of four wires of 5 mm diameter carrying an effective force of 100 kN are available for use. Design the spacings of cables in the two directions and check for the safety of the slab against collapse and excessive deflection at service loads. Assume f_{ck} = 40 N/mm^2 , f_p = 1600 N/mm^2 and E_c = 38 kN/mm^2 .

Rubrics	**1**	**2**	**3**	**4**	**5**	**Total**
Marks						

ASSIGNMENT - 4

Shear and Torsional strength Design

4.1 A prestressed concrete beam (span = 12 m) of rectangular section 120 mm wide and 300 mm deep, is axially prestressed by a cable carrying an effective force of 200 kN. The beam supports a total uniformly distributed load of 5 kN/m which includes the self-weight of the member. Compare the magnitude of the principal tension developed in the beam with and without the axial prestress.

4.2 A prestressed I-section has the following properties: Area = (55×10^3) mm^2 Second moment of area = (189×10^7) mm4 Statical moment about the centroid = (468×10^4) mm^3 Thickness of web = 50 mm It is prestressed horizontally by 20 wires of 5 mm diameter and vertically by similar wires at 150 mm centers. All the wires carry a tensile stress of 900 N/mm^2 . Calculate the principal stresses at the centroid when a shearing force of 100 kN acts upon this section.

4.3 An unsymmetrical I-section is used for a 30 m span prestressed concrete bridge girder having the top flange width and thickness of 1000 and 250 mm, respectively. The web is 1500 mm deep and 200 mm thick. The bottom flange is 600 mm wide and 350 mm deep. The girder is prestressed by cables having an initial tensile force of 5700 kN at an eccentricity of 850 mm at center of span and 180 mm at the supports. The girder has to support an ultimate shear force of 1800 kN at the supports. The loss ratio is 0.85. Estimate the ultimate shear resistance of the support section.

4.4 A prestressed girder of rectangular section 200 mm wide and 300 mm deep, is to be designed to support an ultimate shear force of 160 kN The uniform prestress across the section is 5 N/mm^2. Given the characteristic cube strength of concrete as 40 N/mm^2 and Fe-415 HYSD bars of 8 mm diameter, design suitable spacing for the stirrups conforming to the Indian standard code IS: 1343 recommendations. Assume cover to the reinforcement as 50 mm. Verify your results using any professional structural analysis software.

4.5 A pretensioned girder having a T-section is made up of a flange 250 mm wide and 70 mm thick. The overall depth of the girder is 550 mm. The thickness of the web is 60 mm. The horizontal prestress at a point 250 mm from the soffit is 12 N/mm^2 . The shear stress due to transverse load acting at the same point is 3.0 N/mm^2 . Determine the increase in the principal tensile stress at this point if the T-section is subjected to a torque of 3 kN m.

Rubrics	**1**	**2**	**3**	**4**	**5**	**Total**
Marks						

ASSIGNMENT - 5

Prestressed Compression and Tension Members

5.1 Explain design aspects of prestressed compression members.

5.2 Explain design aspects of prestressed tension members.

5.3 Design a suitable section for the tie member of a prestressed concrete truss to carry a design tensile force of 500 kN. Assume the permissible compressive stress in concrete at transfer as 15 N/mm^2 and tension is not allowed under service loads. Loss of prestress is 20 per cent. High-tensile wires of 8 mm diameter with an ultimate tensile strength of 1600 N/mm^2 with an initial stress of 800 N/mm^2 are available for use. The direct tensile strength of concrete is 2.5 N/mm^2. A load factor of 2 against collapse and 1.25 against cracking is to be ensured in the design. Verify your results using any professional structural analysis software.

5.4 Design the thickness and circumferential reinforcement required for a cylindrical tank wall subjected to a design tensile force of 550 kN/m. f_{ct} = 16 N/mm^2, f_{tw} = –0.8 N/mm^2, direct tensile strength of concrete = 3 N/mm^2 and h = 0.85. High-tensile wires of 5 mm diameter (UTS = 1600 N/mm^2) with an initial stress of 1000 N/mm^2 may be used. Desirable load factors against collapse and cracking should not be less than 2 and 1.25, respectively.

5.5 A prestressed concrete compression member with a square cross-section of 400 mm a side is reinforced with four strands of 12.7 mm diameter at each corner with an effective cover of 50 mm. If f_{ps} = 1650 N/mm^2, f_c = 40 N/mm^2, f_{pe} = 1000 N/mm^2 and E_{ps} = 200 kN/mm^2, construct the load-moment interaction diagram and determine the maximum moment capacity of the section and the corresponding axial load. Assume suitable data regarding the strains in concrete and steel.

Rubrics	**1**	**2**	**3**	**4**	**5**	**Total**
Marks						