Civil Services (Main) Examination, 2009

CIVIL ENGINEERING

(Paper I)

Time Allowed : Three Hours **Maximum Marks : 300**

QUESTION PAPER SPECIFIC INSTRUCTIONS

(Please read each of the following instructions carefully before attempting questions)

There are EIGHT questions divided in two Sections.
Candidate has to attempt FIVE questions in all.
Question Nos. 1 and 5 are compulsory and out of the remaining, any THREE are to be attempted choosing at least ONE question from each Section.
The number of marks carried by a question/part is indicated against it.
Wherever any assumptions are made for answering a question, they must be clearly indicated.
Word limit in questions, wherever specified, should be adhered to.

SECTION 'A'

1. Attempt any five of the following:

(a) A smooth right circular cylinder of radius 0.5 m rests on a horizontal plane and is kept from rolling by an inclined string *AC* of length 1.0 m. A prismatic bar of length 1.5 m and weight 125 N is hinged at point *A* and leans against the cylinder as shown in the figure below. Find the tension *S* that will be induced in the string *AC*.

[Figure: A smooth cylinder with centre C resting on a horizontal plane. Point A is on the plane to the left of the cylinder. String AC runs from the hinge A to the centre C of the cylinder. A prismatic bar is hinged at A, inclined upwards to the right, and rests tangentially on the top-left of the cylinder, its upper end projecting beyond the point of contact] **12**

(b) A composite beam of cross-sectional dimensions is shown in the figure below. The upper 150 mm × 250 mm part is concrete, E_c=20 kN/mm^2 and the lower 150 mm × 10 mm part is strap steel, E_s=200 kN/mm^2. Locate the centroid and calculate the second moment of area about the horizontal centroidal axis of the composite section.

[Figure: Rectangular section 150 mm wide; upper concrete part 250 mm deep; lower hatched steel strap 10 mm deep across the full 150 mm width] **12**

(c) For the beam shown in the figure below, find the fixed moment at ends *A* and *B*, using conjugate beam method. *EI* is constant.

[Figure: Beam AB fixed at both ends A and B, span 10 m; point load 50 kN at 3 m from A; point load 75 kN at 4 m further (7 m from A, 3 m from B)] **12**

(d) A gate of size 2 m × 1 m can slide without friction. It is held in place by a thin cable which pulls it to the left due to buoyancy on a balloon of diameter *D* and of negligible weight. The gate just opens when the level of water is as shown in the figure below. Obtain *D*. Where should the cable be attached so that the gate slides smoothly (i.e., without rotation) inside the channel?

[Figure: Water on the left held by a vertical wall; a horizontal channel leads off to the right through the wall, its opening 2 m high closed by a vertical gate 2 m × 1 m sitting in the opening; the free water surface is 3 m above the top of the channel opening. A spherical balloon of diameter D floats submerged in the water to the left; a cable runs vertically down from the balloon to a pulley near the level of the gate and then horizontally to the gate. Labels: Balloon, Cable, Pulley, Water, Gate 2 m × 1 m, Channel] **12**

(e) An open circular cylindrical vessel of 20 cm diameter and 80 cm height contains water up to a height of 60 cm. Find the maximum rotational speed of the cylindrical vessel about its vertical axis so that no water spills. The vortex flow developed in the circular vessel is forced-type vortex. **12**

(f) Find the coefficients in a cubic polynomial representing velocity profile for a boundary layer flow over a flat plate held parallel to the stream. The pressure inside the boundary layer is impressed from outside boundary layer and remains constant in the direction of **12**

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flow. Find the shear stress on the plate in terms of free stream velocity, boundary layer thickness δ and dynamic viscosity μ. Cubic polynomial

$$u/U=a+b\eta+c\eta^2+d\eta^3$$

where a, b, c and d are coefficients and $\eta=y/\delta$ and y–measured normal to the plate.

2. (a) A bridge girder which is simply supported, is traversed with a system of loads as shown in the figure below. Calculate the maximum shear force and bending moment for the girder when the loads are traversing. Assume the span of the girder as 40 m.

[Figure: Train of five concentrated loads numbered 1 to 5: load 1 = 6 kN, load 2 = 6 kN, load 3 = 10 kN, load 4 = 10 kN, load 5 = 4 kN; spacings 1–2 = 2.5 m, 2–3 = 3 m, 3–4 = 3 m, 4–5 = 2.5 m (total length 11 m)] **20**

(b) Determine the value of collapse load for the continuous beam of constant plastic moment capacity of 90 kN-m shown in the figure below. Use mechanism method.

[Figure: Continuous beam ABCD on simple supports at A, B, C and D; spans AB = BC = CD = 6 m. Span AB: point load P at 2 m from A and point load 1.5P at 2 m from B. Span BC: uniformly distributed load P/6 kN/m over the whole span. Span CD: point load P at 3 m from C] **20**

(c)(i) If the velocity components for possible flow are given as

$$u=-4ax(x^2-3y^2)$$

$$v=4ay(3x^2-y^2)$$

determine whether or not fluid motion is possible. Obtain stream function, ψ. Show whether the flow is rotational or irrotational. If irrotational, find velocity potential, Φ. **10**

(c)(ii) A trapezoidal channel with one side vertical and the other sloping at two horizontal to one vertical, carries a discharge of 28 m^3/sec at a mean velocity of 1.5 m/sec. Determine the longitudinal slope and channel dimensions for the best hydraulic efficiency, if Manning's n=0.014. **10**

3. (a) As shown in the figure, an I-section is made using 3 wooden planks of dimensions 150 mm × 10 mm to give a total depth of 170 mm. The glue that is used to join the planks at the joint is having a permissible shear stress of 1 N/mm^2 after it is cured. Check whether the section is safe at the joint to withstand, when it is used as a cantilever of span 1 m, due to a concentrated load of 1 kN applied at the free end.

[Figure: I-section made of three planks: top flange 150 mm × 10 mm, bottom flange 150 mm × 10 mm, vertical web 10 mm thick and 150 mm deep between the flanges; total depth 170 mm; glue at the two web–flange joints (labelled Glue)] **20**

(b)(i) A model having a scale ratio of 1 : 10 is to be constructed to determine the best design of Kaplan turbine having power 7355 kW under a net head of 10 m at a speed of 100 r.p.m. If the net head available at laboratory is 6 m and the model efficiency is 88%, find– (1) the speed of the runner required in the laboratory; (2) the output power of the model; (3) the specific speed in each case; (4) the discharge needed in the model. **10**

(b)(ii) Two pipes each 100 m long and diameters 50 mm and 100 mm respectively, are arranged in parallel between two reservoirs which have difference of water levels as 10 m. If friction factor for each pipe is same as f=0.04, calculate the rate of flow through each pipe. Neglect minor losses. Use $h_f=fLV^2/2gd$ formula. **10**

(c) An overflow spillway as shown in the figure below is 50 m high. At the design head of 2.5 m over the spillway, find the sequent depth and energy loss in hydraulic jump formed on the horizontal apron at the toe of the spillway. Neglect energy loss over the spillway. Assume coefficient of discharge over the spillway, C_d=0.74. Find also the percentage of energy loss occurred in hydraulic jump. Use specific energy concept to find h_1, the supercritical depth of flow of hydraulic jump.

[Figure: Overflow spillway 50 m high above the horizontal bed/apron, with water surface 2.5 m above the crest on the upstream side. The nappe flows down the spillway face to the horizontal apron at the toe, where the supercritical depth is h_1 with velocity v_1; a hydraulic jump forms downstream with subsequent depth h_2 and velocity head $v_2^2/2g$ marked above it; the energy loss h_L is marked as the vertical distance between the upstream energy level (dashed line at the upstream water level) and the downstream energy line] **20**

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4. **(a)(i)** A straight bar 2 m long and of 25 mm × 5 mm cross-section is compressed longitudinally until it buckles. Assuming Euler's formula to apply to this case, estimate the maximum central deflection before the material passes a yield point at 320 N/mm^2. Take E=200 kN/mm^2, assuming both ends are hinged. **15**

(a)(ii) If the bar is fixed at both ends, calculate the Euler's load. **5**

(b) In a structure, a beam is loaded with a concentrated load of 100 kN acting at 3 m from one of the supports on a span of 5 m. The beam may be assumed to be simply supported. If the deflection under the load is not to exceed 6 mm, find the depth of the beam, assuming it to be of rectangular cross-section. Assume the width of the beam as 200 mm and E=200 kN/mm^2. **20**

(c)(i) A run-of-river hydroelectric power station is proposed across a river at a site where net head available is 20 m on turbine. The river carries sustained minimum flow of 30 m^3/sec in dry weather and behind the power station, sufficient pondage is provided to supply daily peak load of demand with a load factor of 70%. Assuming the plant efficiency of 55%, determine the maximum generating capacity of the generator to be installed at the powerhouse. If the daily load pattern indicates 21 hours of average load and 3 hours of peak load, determine the volume of pondage to be provided to supply daily demand. **12**

(c)(ii) At a proposed hydroelectric station, the available head is 80 m and it is estimated that 36000 litres per second of water is available throughout the year for operating turbines. The turbines are to run at 500 r.p.m. and the overall efficiency is 85%. The specific speed of the turbines is nearly 180. Determine the maximum available power and the number of turbines required. **8**

SECTION 'B'

5. Attempt any five of the following:

(a) In a laboratory test for a mix design, the coarse aggregates and fine aggregates are sieved and weight retained on each sieve are given in the table. Find the fineness modulus for each:

Sl. No.	IS Sieve	Weight retained in kg for coarse aggregates	Weight retained in gm for fine aggregates
1	40	2.1	–
2	20	2.9	–
3	10	1.45	–
4	4.75	2.55	20
5	2.36	1.00	100
6	1.18	–	100
7	600 μ	–	190
8	300 μ	–	350
9	150 μ	–	240
Total		10	1000

12

(b) In a powerhouse to replace a circular penstock of 1.2 m diameter is made out of 12 mm thick plate, lapping it and securing it by traverse fillet welds of 10 mm size, provided on the inside and the outside as shown in the figure. What safe internal pressure can be allowed in the penstock? Assume the permissible stress in weld as 110 MPa.

[Figure: Cross-section of the circular penstock, radius 0.6 m (marked from the centre), shell plate 12 mm thick, internal pressure *p*? shown by radial arrows; the lapped plate joint is secured by fillet welds of 10 mm size on the inside and the outside (labelled "Fillet weld" and "Fillet weld 10 mm")] **12**

(c) A pretensioned concrete beam 100 mm wide and 300 mm deep is prestressed by a steel wire carrying an initial force of 200 kN at an eccentricity of 45 mm. If E_s and E_c are 210 kN/mm^2 and 35 kN/mm^2 respectively, estimate the percentage loss of stress in steel due to elastic deformation. Assume the area of steel is 200 mm^2. **12**

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(d)(i) Compute the void ratio of sand in the loosest possible state, considering it to be made up of equal diameter spherical particles. **5**

(d)(ii) A clayey soil with specific gravity of 2.70, has natural moisture content of 16 percent at 70 percent degree of saturation. What will be its water content if after soaking, the degree of saturation becomes 90 percent? **7**

(e) The coefficient of consolidation (C_v) of a clay was found to be 0.955 mm^2/min. The final consolidation settlement for a 5 m thick layer of this clay was calculated as 280 mm. Assuming a uniform initial excess pore-water pressure distribution and permeable layer to be present both above and below the clay layer, compute the settlement time for– (i) 90 percent primary consolidation (take T_v=0.848 for U=90%); (ii) settlement of 100 mm. **12**

(f) A 5 m high smooth retaining wall with vertical face retains a cohesive backfill having unconfined compressive strength of 30 kN/m^2, γ=18 kN/m^3 and ϕ_u=0 . Calculate the depth of tension crack and the total active earth pressure, assuming the tension crack has fully developed. The backfill surface is horizontal. **12**

6. (a) A circular steel pipe of 150 mm and 10 mm thick is welded to a rectangular plate of 12 mm thick by fillet weld around the pipe. A vertical load of 10 kN is acting on the pipe at a distance of 400 mm from the weld in the longitudinal direction and 300 mm from the centre of the pipe transversely. Design the weld. **20**

(b) A lounge in an office building is circular in plan, supported on four columns and connected by circumferential beams at top connecting the columns. The diameter of circumferential beam is 6 m. Design a suitable slab for the above system, taking 5 kN/m^2 as the superimposed load. Adopt M 20 grade concrete and Fe 415 grade steel. **20**

(c)(i) State the limitations of plate load test used for finding the bearing capacity of soil. **5**

(c)(ii) A circular footing of 3 m diameter has to carry a gross load of 4500 kN. The foundation soil is clayey sand having C=8 kN/m^2, ϕ=30 and γ=20 kN/m^3. Find the depth at which the footing should be placed for factor of safety of 2.5. For ϕ=30 – N_C=30.1, N_q=18.4, N_γ=22.4 **15**

7. (a) Design a suitable single lacing for the column whose cross-section is shown in the figure. The slenderness ratio for the column is 24. Use 65 mm × 15 mm plate for lacing. Axial load on the column is 1750 kN. For the column section r_{xx}=146.3 mm r_{yy}=40.3 mm For lacing plate

l/r	σ_c (MPa)
100	84
110	75.3
120	67.1
130	59.7

[Figure: Built-up column of two ISWB 350 @ 599 N/m sections placed side by side (webs parallel), connected by single lacing on the flanges (labelled “Lacing”). Each flange is 200 mm wide, with 100 mm from the outer flange edge to the web centre line; the centre lines of the two webs are 300 mm apart; the lacing is connected to the flanges on a line marked 50 mm from the flange edge] **20**

(b)(i) A group of concrete bored piles is square in plan and consists of four piles, each 10 m long and 500 mm in diameter. The piles are installed at a spacing of 1 m c to c in a deep clay deposit having an unconfined compressive strength of 60 kN/m^2. At the tip of the pile and below, the undrained shear strength of the clay C_u=40 kN/m^2. The average unit weight of the soil and concrete are 18.5 kN/m^3 and 22.5 kN/m^3 respectively. Estimate the total ultimate bearing load of the piles group. Take mobilisation factor equal to 0.5. **16**

(b)(ii) Classify the piles with respect to their use. **4**

(c)(i) Find the ratio of horizontal permeability to vertical permeability for a soil deposit consisting of three layers. The second layer has the permeability ten times that of the first layer and the thickness half that of the first layer. The third layer has thickness twice that **10**

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of the first layer and permeability twice that of the second layer.

(c)(ii) An excavation has to be made in a 10 m deep clay stratum underlain by a bed of sand. In a trial borehole made, the groundwater was found to rise to an elevation of 3.5 m below GL. What is the safe depth of excavation without its bottom becoming unstable due to uplift pressure of groundwater? If the excavation has to be made safely up to a depth of 8 m, what is the depth up to which water table should be lowered in the vicinity of the trench? Take specific gravity of clay as 2.7 and void ratio of clay as 0.7. **10**

8. (a) In a multistoreyed building, it is proposed to provide a rectangular column of size 400 mm × 600 mm reinforced with 6 numbers of 25 mm ϕ bars. Use M 25 grade concrete and Fe 415 grade steel. Find the ultimate concentric load capacity of the column. What will be the ultimate load capacity when $e_{min} \not> 0.05$ lateral dimension? Design the lateral ties also. **20**

(b) A prestressed concrete beam of section 250 mm wide by 400 mm deep is used over an effective span of 7.5 m to support an imposed load of 4 kN/m. The unit weight of concrete is 25 kN/m^3. At the centre of the span, find the magnitude of– (i) the concentric prestressing force necessary for zero fibre stress at the soffit when the beam is fully loaded; (ii) the eccentric prestressing force located at 140 mm from the soffit of the beam which will nullify the bottom fibre stresses due to loading. **20**

(c)(i) What do we obtain from a consolidation test? List the parameters we obtain. Describe how one can use these parameters in the design. **12**

(c)(ii) In a consolidation test, a specimen whose void ratio was 1.068 under effective pressure of 214 kN/m^2 changed to 0.994 when effective pressure was increased to 429 kN/m^2. Compute the coefficient of compressibility, compression index and coefficient of volume compressibility. **8**

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