Prestressed and composite concrete structure

The work consists of two parts:

A. Post-tensioned cast in-situ continuous beam with parabolic tendons and anchors
B. Pre-tensioned precast beam with straight strands which functions as a composite structure together with slab casted on the beam.

In the both part of the work the beam structure is designed in the same building.

In the work should be made for the beam /composite structure:

- Design calculations for beams in the middle modul line 2
  - part A: 2-span continuous beam with parabolic tendons
  - part B: 1-span precast beam unit which is made 2-span continuous beam by the topping of the slab structure
- Drawings
  - part A: Dimension and reinforcement drawing of 2-span continuous cast-in situ beam
  - part B: Plan drawing with dimensions and loading,
    - dimension and reinforcement drawing of the precast beam
    - joint detail of the beam and the slab
    - joint detail of the beam and the column

The exercise will be done with 2 persons group.
The intermediate check points are obligatory.
Each group presents their work to all other groups.

The calculations are made according EuroCodes:
EC0: SFS-EN 1990-1 Design principles (combination coefficients, partial safety factors for loads)
EC1: SFS-EN 1991-1 Loads
EC1: SFS-EN 1991-1-6 Actions during execution
EC2: SFS-EN 1992-1-2 Design of concrete structures, General rules, Structural fire design (location of the reinforcement, minimum dimensions)
Desing calculations:
The calculations are supplied with the cover page where is the title label

In the calculations there are:

Part A:
- The description of the structure
- Loads
- Choosing the depth of the beam
- Choosing the required prestressing force, number of tendons, the tendon profile and the eccentricities.
- Section forces (bending moment, shear force, balancing forces at the different points; the critical load combination taking into account moving live load),
- Prestress losses (Prestress -> imposed loading stage -> final stage)
- Stresses of concrete and strands, deflection (at the point of max. field moment and at the middle support)
  - at the prestress stage
  - when the imposed loads come
  - final stage ($t=\infty$)
- Checking against cracking (quasi-permanent and frequent combination, at the point of the max. field moment and the middle support)
- Flexural and shear resistances in the ultimate limit state (at the point of the max. field moment and the middle support)
- Reinforcement in the end block against spalling and splitting.

Part B:
- The description of the structure
- Loads (from the part A)
- Choosing the depth of the beam
- Section forces (bending moment, shear force, the critical load combination taking into account moving live load) from the part A
- Required number of strands and the prestressing force, initial prestress
- Prestress losses (before transfer, transfer -> casting the topping -> imposed loading stage -> final stage)
- Stresses of the precast beam (concrete and strands) and deflection at the stage of the casting the topping
- Stresses of the structure (concrete and strands), deflection
  - imposed loading stage
  - final stage
- Stresses and deformation and secondary moment at the middle support due to differential shrinkage and creep between the precast beam and the topping
- Flexural and shear resistance of the precast beam during execution taking into account the live load during execution.
- Flexural and shear resistance of the composite cross-section at the final stage.
- Shear resistance and the stirrups of the interface between the precast beam and the
- Shear resistance between the beam web and the
- Required top reinforcement at the middle support
- Possible propping during the execution before the topping concrete is
- Reinforcement against splitting and spalling at the end of the precast beam.
- Joint between the column and the beam unit (neopren, bar)
- Reinforcement for the openings of the beam; shear resistance of the web between the openenings
For the calculation of the section forces (bending moment, shear force) the using of computer is allowed (frame program, composite beam program, FEM), but the magnitude of the forces should be checked by the hand calculation.

Using of dimensioning programs is allowed for the preliminary dimensioning (choosing proper dimensions), but the raw checking of the magnitude of the results should be done by the hand calculation.

In the final dimensioning the dimensioning calculations must be presented in detail. All the formulas and the values used in the formulas must be presented clearly. Using of MathCadiä or spreadsheet programs are allowed, but the calculations must be presented in detail with the formulas used in the calculation.

The presentation of the calculations is done according to RIL 137 Rakennelaskelmaohje (guide of the design calculations and model calculations).
Drawings:

Part A:
Dimension and reinforcement drawing of the continuous post-stressed beam:
- tendon geometry (distance of the tendon from the bottom of the beam about distance of 1 m)
- number of tendons and strands in one duct, duct diameter, initial prestressing force
- Required reinforcement, stirrups, spalling reinforcement, anchor reinforcement
- Concrete grade, steel grades, concrete cover, exposure class, fire rate, design working life

Part B:
1. Drawing of the slab field:
   - modul lines, modul dimensions
   - depth of the slab (precast plank/total depth) and the uniformly distributed areal loads
   - beam identification codes
   - detail and cutting marks
   - propping of the beam and force of the propping if needed

2. Dimension and reinforcement drawing of the precast beam unit for manufacturing:
   - beam dimensions
   - strands, initial prestress, unbonding of strands (which strands and length of the debonding) if needed
   - other reinforcement (stirrups, palling reinforcement, anchor reinforcement, links at the interface)
   - reinforcement due openings of the beam
   - bending list of the reinforcement bars
   - uniformly distributed line load of the beam
   - Concrete grade, steel grades, concrete cover, exposure class, fire rate, design working life

3. Joint details (page size A4, cover page)
   - Cutting where is shown the joint between the beam and the slab
   - Beam-column joint detail

Drawing size A1 or A3, joint details A4

There is the title label in every drawing and in the cover page of the calculations.

The drawings are done according to RIL 84 Rakennuspiirustusohje or RIL 158 CAD Rakennuspiirustusohje and RIL 229-1 and RIL 229-2 Rakennesuunnittelun asiakirjaohje, Mallipiirustukset ja –laskelmat (Guides for the building drawings, model drawings)

Presentation of the work Mo 7.9

Leaving the work Mo. 7.12
1. Ma 28.9 Osa A: Poikkileikkaus, jänneteräkset ja jänteiden kulku, voimasuureet
2. Ma 19.10 Osa A: Jännityshäviöt, jännitykset, taipumat, taivutus- ja leikkauskestävyys
3. Ma 26.10 Ryhmät esittelevät työnsä tuloksia kaikille
4. Ma 2.11 Osa B: Poikkileikkaus, punosmäärä, jännityshäviöt
5. Ma 16.11 Osa B: Taivutus- ja leikkauskestävyys, työsauma
6. Ma 23.11 Kukin ryhmä esittelee oman työnsä tuloksia kaikille
7. Ma 7.12 Harjoitustyön palautus
8. Ma 14.12 Korjattavaksi määrättyjen harjoitustöiden palautus

Intermediate check points:
1. Mo 28.9 Part A: Cross-section, prestressing tendons, tendon profile, section forces
2. Mo 19.10 Part A: Pressessing losses, stresses, deflection, flexural and shear resistances
3. Mo 26.10 The groups present their work to all other groups.
4. Mo 2.11 Part B: Cross-section number of strands, prestress losses
5. Mo 16.11 Part B: Flexural and shear resistances, construction joint
6. Mo 23.11 The groups present their work to all other groups
7. Mo 7.12 Leaving the work
8. Mo 14.12 Leaving the prepared works.

**Leaving the work: Mo 7.12**

Previous knowledges:
Rak 43.3110 Lectures and exercises
Rak 43.3130 Working exercise I of concrete structures
Statically in-determinate frame structures
The calculations are made according EuroCodes:
EC0: SFS-EN 1990-1 Design principles
EC1: SFS-EN 1991-1 Loads
EC1: SFS-EN 1991-1-6 Actions during execution
BY 60 Suunnitteluohje EC2, osat 1-1 ja 1-2 (In Finnish)

References:
Rak 43.3110 Lectures and exercises
Rak 43.3136 Material given in the course (mainly in Finnish)
Rak 43.3130 Material of the working exercise I of concrete structures (in Finnish)

Betonirakentamisen ohjeisto, Valmisosarakentaminen II (in Finnish):
Osa H: Perustus- ja runkorakenteet (palkkien kuormituskäyriä)
(Foundation and skeletal structures (loading curves of beams)
Osa I: Liittorakenteet (Composite structures)

Runko-BES (in Finnish):
Julkaisu 7: Liitokset (Joint details of precast units)
Julkaisu 8: Teräsbetonipalkit (Reinforced concrete beams)

BY 210 Matti Leskelä: Betonirakenteiden suunnittelu ja mitoitus
BY 131 Paasikallio, Mikkola, Nyman: Jännebetonirakenteidenmekaniikka ja mitoitus
BY 204 Paasikallio & Kanerva: Betonirakenteiden mitoitustehtävät ratkaisuineen

Gilbert & Mickleborough: Design of Prestressed Concrete
Collins & Mitchell: Prestressed Concrete Structures
T.Y. Lin & Burns: Design of Prestressed Concrete Structures
Ghali & Favre: Concrete Structures, Stresses and Deformation

In Finnish:
RIL 137 Rakennelaskelmaohjeet soveltuvin osin (Guides for desing calculations of building structures, model calculations)
RIL 84 Rakennuspiirustusohjeet tai RIL 158 CAD piirustusohje (Guides for building drawings, model drawings)
RIL 229-1 ja RIL 229-2 Rakennesuunnittelun asiakirjaohje, Maalipiirustukset- ja laskelmat
(Guides for the design documents, model drawings and model calculations)

Liitosdetaljit (in Finnish): (Joint details of precast units)
Runko-BES: Julkaisu 7: Liitokset
www.elementtisuunnittelu.fi/runkorakenteet/liitokset (the newest joint details, neopren pad)
www.elementtisuunnittelu.fi/runkorakenteet (mitoituskäyröstöt, loading curves)
www.elementtisuunnittelu.fi/fin/Haku?Term=HI, hakutulos 33 : (search result 33)
Jännitettyjen I- ja HI-palkkien suunnittelutaulut (in Finnish, Guide for the calculation of prestressed i- and saddle I-beams)
www.parma.fi/Ammattirakentajalle/suunnittelu Mitoituskäyröstöt, suorakaide ja leukapalkit
(loading curves of precast rectangular and L-beams)
Task:
Design the beams in the module line 2 of a floor for parking of cars. The floor is in the outdoor.
Part A: The beams are post-stressed cast-in-situ beams with parabolic tendons
Part B: The beams are prestressed precast beams with straight tendons. The precast beams are acting as a composite beam with the cast-in-situ slab.
The slab is cast-in-situ one way slab which is supported by the beams. On the slab is the structure described below.

Distance between the columns in the beam direction:
L1 = ______ mm    L2 = ______ mm
Distance between the beams    L3 = ______ mm

Column dimension in the direction: 480 mm, column concrete grade C35/45-1

The structure of the floor:
- asphalt    _____ mm
- reinforced concrete slab    _____ mm
- gravel    _____ mm
- water insulation
- inclination concrete    ≥ _____ mm
- reinforced concrete slab    h= _____ mm

Loading:
Dead load according to the structure above
Uniformly distributed live load according to EN 1991-1 for traffic areas (checking for point load is not needed)
Vehicle weight is ≤__________ kg

In the part B the beams are checked also for the live load during construction according EN-1991-1-6

Exposere class:
The structure is in outdoor, the surface of the slab can be exposed by salt.
The exposure class is chosen according to SFS-EN-1991-1-1 taking into account the requirements mentioned above.
The design working life of the structure: ______ years
Fire rate : ______

The temperature is supposed to be +20 oc during the hardening of the concrete

The beams are not allowed to crack under the frequent load combination.
Part A:
The beam is post-stressed cast –in situ continuous beam. The beam is treated as a rectangular cross-section. The slab does not act as a part of the effective cross-section, it produce only a dead weight. At the moment of prestressing stage the slab is casted and the beam is loaded by the weight of the slab. The joint between the beam and the column is pinned.

Materials:
beam Concrete grade of : C _____ / _____ -1
Presstressing time _____ days from the casting of the beam
Prestressing steel: \( f_{p0,1k} / f_{pk} \) St 1630 / 1860 , relaxation 2.5 % during 1000 h at the stress level 0.7 \( f_{pk} \)
Reinforcement steel: High bond steel grade S500 (\( f_{yk} = 500 \) MPa)

Prestressing method:
VSL-prestressing method:
Friction coefficient \( \mu = _____ \)
Wobbling coefficient \( \beta = _____ \) rad/m
End release: anchorage slipping _____ mm
Duct diameter, number of the strands in one duct, the eccentricity of the strands about the centroid of the duct, the dimensions of the anchor, the edge distance and the distance between the anchors are given in the appendix.

Loading time of the imposed loads: _______ days after the casting of the beam
Part B:

The beams are precast rectangular beams with straight prestressed tendons. The beams are simply supported with one span.

The precast plank slab is assembled on the beams and above the plank slab there is cast-in situ topping acting together with the precast plank as a composite structure. The precast plank acting as a mould for cast-in situ concrete.

The beams and the slab (precast plank + topping) are connected together so that when the topping is hardened they (precast beam + precast plank + topping) is acting as a composite continuous T-beam where the slab structure is the compressive flange of the beam. In the negative moment area the top reinforcement is located in the topping.

The precast plans are not propped so the weight of the plank and the topping comes to the precast beam at the stage of casting the topping. During this stage there is also live load during execution according to EN-1991-1-6.

The beams are not heat treated; the temperature is assumed +20 °C during the hardening of the beam concrete.

Concrete strength at the transfer of the prestress $f_{cm}/f_{cm}$

The beams and the precast planks are assembled at the age _____ days

The loading time of the imposed design loads _____ days after the casting of the topping

Materials:

Concrete:
- Precast beam: $C _____ / _____$
- Precast plank: $C _____ / _____$
- Topping: $C _____ / _____$
- Joint concrete: $C _____ / _____$

Prestressing steel: $f_{01k}/f_{pk}$ St 1630/1800, relaxation 2.5% during 1000 h at the stress level 0.7 $f_{pk}$

Reinforcing steel: High bond steel S500

Openings in the beam:
- Distance from the edge lines A and C: $a_1 = ________$ mm
- Centre distance between the openings: $a_2 = ________$ mm
- Diameters of the openings: $dr = ________$ mm

The openings are symmetrically about the depth of the precast cross section.
Prestressed and composite concrete structure
### VSL- MULTI STRAND SYSTEM

<table>
<thead>
<tr>
<th>Strands pcs/one duct</th>
<th>Inner diameter of the duct mm</th>
<th>Eccentricity of the tendon in the curved duct osilla mm</th>
<th>Anchor dimensions Concrete strength $f_{cm} \geq 33$ MPa</th>
<th>Edge distance of the anchor</th>
<th>Distance between the anchors c/c mm</th>
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