

CVX7640 - Structural Design

FINAL EXAMINATION - 2024/2025

Time Allowed: Four (04) Hours

Date: 2026 - 02 - 26 (Wednesday)

Time: 0930 - 1330 hrs.

Paper consists of five (05) questions. Answer any four (04) questions.
You may use the Block III named "Structural Design Extracts From Codes" provided to you with the course material, which also contain concrete design charts & steel sectional properties
You may assume and state reasonable values for any factors not provided.

Q1. A Class 1 pretensioned concrete beam (with a Box Section as in Figure Q1) is proposed to support a flat roof of a school pavilion as a simply supported beam spanning 15 m. It carries only its own weight at transfer. Proposed section of the prestressed beam, material properties and its loading are as follows;

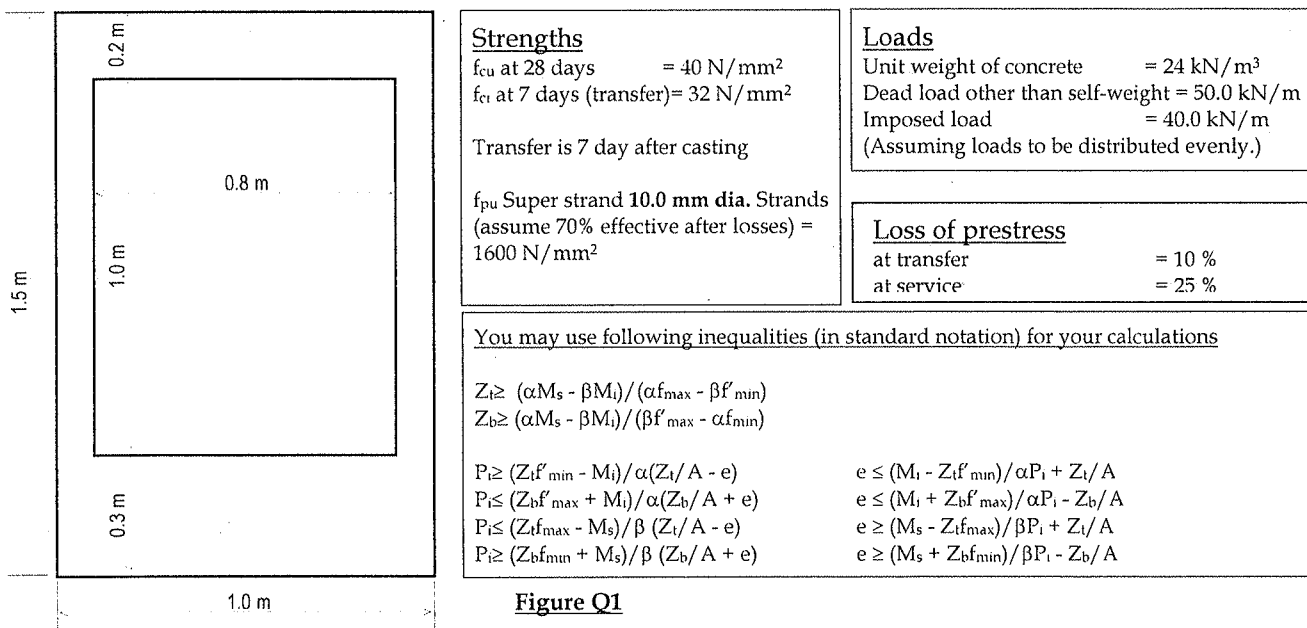


Figure Q1

Using the above data, design the prestressed concrete beam according to the following steps.

- Show that the area of the section $A = 0.7 \text{ m}^2$ and bottom fiber to centroid of the section $Y_b = 0.69 \text{ m}$.
 - If the second moment of area, $I = 0.21 \text{ m}^4$, find the section moduli of the section Z_b and Z_t (03 Marks)
- Evaluate the dead and imposed loads on the beam at transfer and in service and calculate the critical bending moments at the two instances. (02 Marks)
- Check the adequacy of the section in carrying the stresses at transfer and in service for the given spans (02 Marks)
- State the four stress conditions applied in the beam for mid span critical section. (04 Marks)
- There is a suggestion to use eccentricity 'e' as 650 mm. Can you agree with that? State your answer with valid reasons. (Cover for the $r/f = 30 \text{ mm}$, Shear Link Diameter = 10 mm) (01 Mark)
 - By using given 'e' value or most appropriate 'e' value find the number of tendons required for the most critical section. (04 Marks)
- Show the details given in the tendon arrangement in v.) is appropriate for tendon spacings (01 Mark)
- Check whether the given tendon arrangement is suitable for the support of the beam. If not propose a solution to this problem. (Calculation is not necessary) (02 Marks)
- Check the suitability of the designed section with respect to Ultimate Moment capacity. (03 Marks)
- Check the suitability of the designed section considering ultimate shear strength of the beam. (03 Marks)

Q2.

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Figure Q2 shows the plan and elevation of a masonry structure for a community building. First and second floors are reinforced concrete slabs 125mm thick. Walls are constructed with locally made high quality bricks and their dimensions are 210mm*105mm*50mm, length, breath, height, respectively. Half brick wall construction is 105 mm, one brick wall construction is 220 mm, one & half brick wall construction is 335 mm. Further, the total wall thickness of the ground and the first floors are 355 mm and 240mm, respectively. The stair cases are externally fixed and do not contribute to loadings of the building.

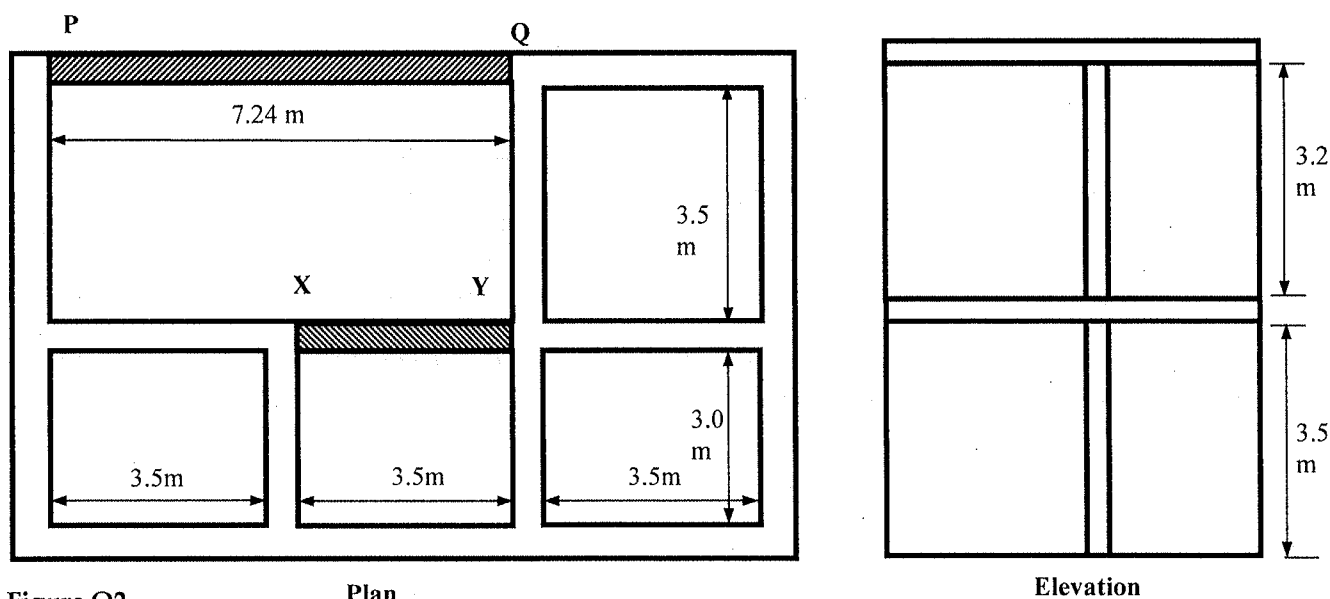


Figure Q2

Plan

Elevation

LoadsImposed load on the first floor slab = 3.5 kN/m²Imposed load on the second floor slab = 2.5 kN/m²**Geometry**

Ground floor to first floor height = 3.5 m

First floor to second floor height = 3.2 m

Material PropertiesUnit weight of RC = 24.0 kN/m³Unit weight of masonry = 22.0 kN/m³

Mortar Designation II

Compressive Strength of Brick = 5.0 N/mm² γ_m for compression and flexure = 3.5

Water absorption - between 7%- 12%

Part I

- Evaluate characteristic dead and imposed loads acting on the internal wall X-Y (at the ground floor level). (03 Marks)
- Find different load combinations and corresponding design loads and eccentricities at the first floor level. (04 Marks)
- Determine the slenderness ratio of the wall (first floor level to second floor level) and compare with its permissible value. (02 Marks)
- Determine the vertical load resistance of the internal wall X-Y at the ground floor level. (02 Marks)
- Check whether the internal wall (ground floor level to first floor level) is able to carry the design compressive load considering vertical load resistance of the wall. (01 Mark)

Part II

- Draw a figure showing boundary conditions for the external wall P-Q in 1st floor level to 2nd floor level. (02 Marks)
- Check the limiting dimensions of the wall panel P-Q. (01 Mark)
- Determine the bending moments parallel and perpendicular to the bed joint if it is subjected to a lateral load of 4.0 kN/m² from the 1st floor level to the 2nd floor level. (06 Marks)
- Check the safety of the external wall panel under wind loads considering moment failure. (04 Marks)



A Mezzanine Floor is to be constructed in the Block 1 building of the Department of Civil Engineering at Nawala, where many hydraulic engineering related laboratory tests are carried out. It had been decided by the Engineer that the floor would be done entirely in a high strength class timber, abutting two right angle placed walls in the building. As shown in the Plan (Figure Q3A) and a Cross-Section (Figure Q3B) of the proposed mezzanine floor, the structure is to be finally supported on corbels protruding from the walls and a timber column. The floor is to be a wooden plank decking supported by a timber beam framework.

Longitudinal beams support the transverse beams topped by the decking planks. Longitudinal beams are supported on corbels extending from the walls and on a timber column at one corner.

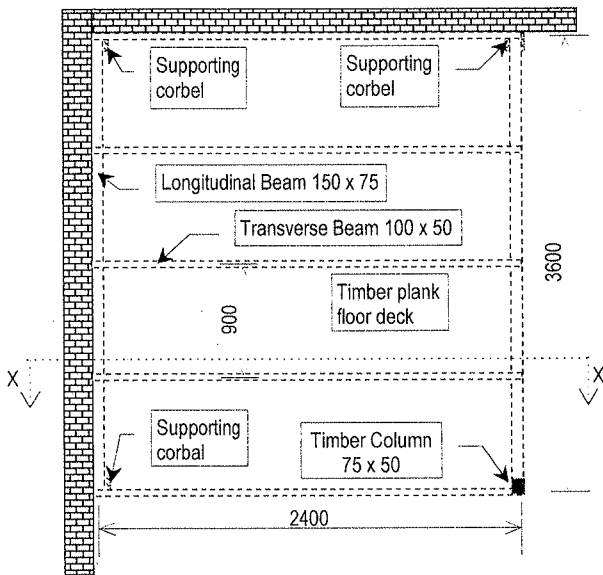


Figure Q3A – Plan of the Mezzanine Floor

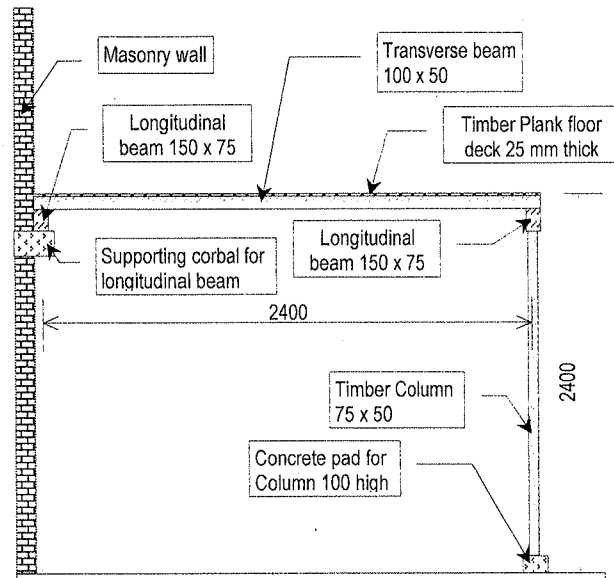


Figure Q3B – Cross Section X-X of the Mezzanine Floor

Loads:

Imposed load on the floor = 1.0 kN/m^2

Note:

In your calculations all relevant loading durations (ex. Long term, Medium term) should be considered.

Assumptions

- Halmilla Timber (Class D70) for all applications
- Exposure condition is Wet

Check the design adequacy of a **Transverse beam** according to BS 5268-1996, using following steps;

- Evaluate the loading on a Transverse Beam due to **live and dead loads** and sketch Bending Moment and Shear Force diagrams for relevant loading durations and check the proposed flexural member against **lateral stability** criteria. (03 Marks)
- Compute the applied **bending stress** at the critical section of a beam and check whether this is within the permissible limit for the flexural member. (03 Marks)
- Check whether the **maximum allowable deflection** is within the permissible limit which is generally equal to $0.003L$. (03 Marks)
(You may use; $\text{Deflection at midspan} = 5wL^4 / (384EI)$ Simply supported section loaded with a udl)
- Check whether the flexural member is safe against failure due to **shear**. (03 Marks)
- Check the **bearing** adequacy at the supports of a transverse beam. (03 Marks)
- Comment on the selection of **timber Class** and **section size** of the transverse beam. (01 Mark)

Check the design adequacy of the structural timber **column** according to BS 5268-1996, using following steps;

- Evaluate the loading (including moment due to nominal eccentricity) on the column due to **live and dead loads** and check for slenderness limits. (03 Marks)
- Compute the applied maximum **compressive stress** in the column and check whether this is within the permissible limit. (03 Marks)
- Check the column for combined flexural (due to nominal eccentricity) and compressive stresses. (03 Marks)

Q4.

A typical floor plan and a sectional view of a three storied commercial building is shown in Figure Q4A and Figure Q4B. The beams are cast monolithically with the floor slab.

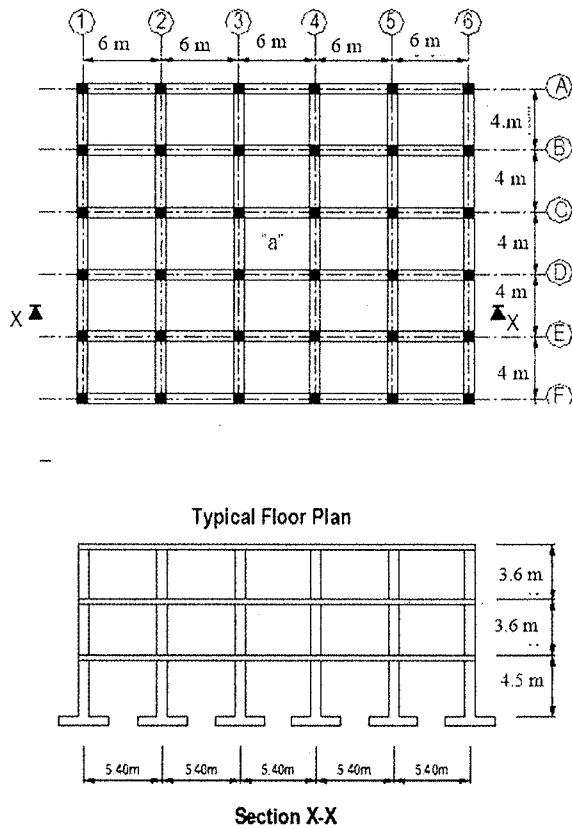


Figure Q4A: Floor plan and a sectional view

Strength of materials:

Grade of concrete = 30
 Characteristic strength of steel
 Main r/f = 460 N/mm²
 Shear r/f = 250 N/mm²
 Nominal cover for reinforcement = 20 mm

Order of floors – Ground, 1st, 2nd, Roof

* Required design charts are provided in 'Code Extracts'

Loads on the structure:

Imposed load on the roof = 1.0 kN/m²
 Dead load by finishes on floors & roof = 1.0 kN/m²
 Imposed load on floors = 3.0 kN/m²
 ** You may neglect the effects of Wind

Thickness of floor & roof slabs = 150 mm

Weights of materials

Unit weight of RC = 24.0 kN/m³

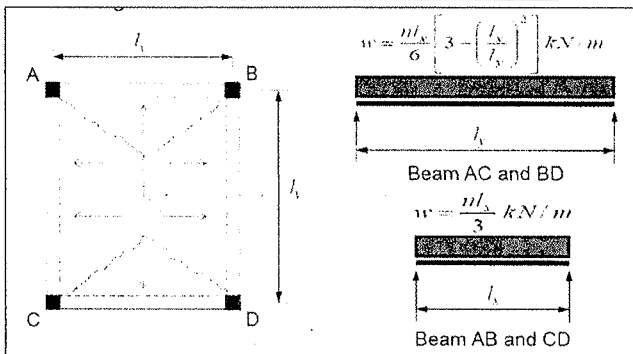


Figure Q4B: Equivalent UDL load transferred from slab to beam

Q 4.1

Reinforced concrete slab panel 'a' at first-floor level, shown in Figure Q4.1, is to be analysed and designed.

- 4.1.1 Calculate the design ultimate load per unit area (kN/m²) acting on slab panel 'a'. (02 marks)
- 4.1.2 Using the moment coefficients specified in BS 8110-1:1997, determine the design bending moments at the governing sections of slab panel 'a', namely at mid-span and along the supports. (02 marks)
- 4.1.3 Provide the reinforcement design at the mid-span of slab panel 'a' in the shorter span direction in compliance with code provisions. (03 marks)

Q 4.2

A continuous reinforced concrete beam ABCDEF located on grid line 4 is required to be designed. The beam section is 400 mm × 300 mm.

- 4.2.1 Determine the ultimate design loading on the beam, assuming that slab loads are transferred as uniformly distributed loads along the beam length, as indicated in Figure Q4.2. (02 marks)
- 4.2.2 Evaluate the design bending moments at the critical sections of the beam using the coefficients given in Table 3.5 of BS 8110-1:1997 for continuous beams subjected to uniform loading. (02 marks)
- 4.2.3 Design the longitudinal reinforcement required at the mid-span of span AB of the beam. (02 marks)

Q 4.3

The reinforced concrete column C4, positioned at the intersection of grid lines C and 4, is to be designed. The column dimensions are 300 mm × 300 mm.

- 4.3.1 Assuming the column is unbraced and that beams framing into the column do not transmit bending moments, calculate the factored axial load on column C4 at ground floor level. (02 marks)
- 4.3.2 Using the simplified approach recommended in BS 8110-1, determine whether the ground-floor column C4 should be classified as a short column or a slender column. (02 marks)
- 4.3.3 Design the reinforcement for the ground-floor column C4. (02 marks)



Q 4.4

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A square reinforced concrete pad footing is to be designed to support column C4. The supporting soil consists of dense gravel, and the allowable bearing capacity of the soil is 600 kN/m^2 .

- 4.4.1 Check whether a footing with dimensions $1500 \text{ mm} \times 1500 \text{ mm} \times 300 \text{ mm}$ is adequate. If it is not satisfactory, propose an appropriate footing size. (02 marks)
- 4.4.2 Evaluate the bending moment at the critical section and design the required reinforcement. (02 marks)
- 4.4.3 Verify that the footing is safe against punching shear at the critical section. (02 marks)

Q5.

A primary beam AB of a four storey steel office building needs to be designed according to BS5950-1:2000. The loads on the beam (including beam self-weight) are shown in Figure Q5A. The beam is laterally restrained and considered simply supported at both ends. The dead and live loads from the secondary beams are acting as point loads on the primary beam at points C and D. UB $457 \times 191 \times 67$ steel sections are used for the primary beams. Take $P_y = 275 \text{ N/mm}^2$. (You have to mention the relevant clauses and tables of BS5950-1:2000 near your calculation steps.) Sectional properties of UB $457 \times 191 \times 67$ steel sections are given in Table Q5A.

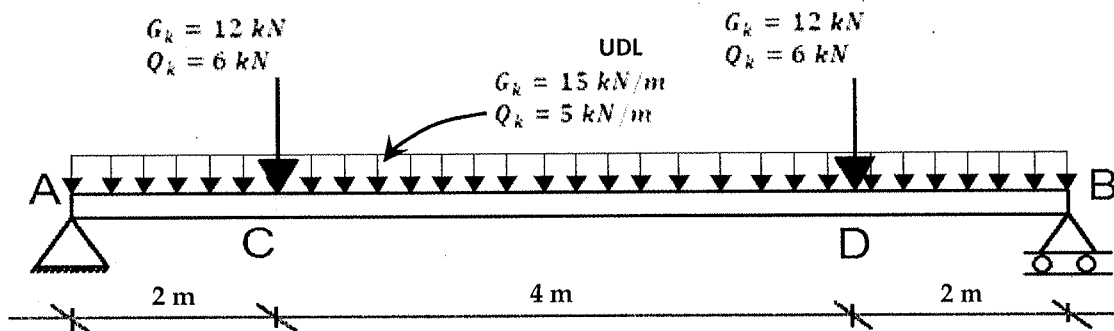


Figure Q5A

- Calculate the design loads on the beam AB and draw the bending moment and shear force diagrams of the beam AB. [05 Marks]
- Do the section classification and identify the class of the steel section used for Beam AB. Briefly explain the importance of "section classification" in structural steel designing. [04 Marks]
- Check the adequacy of the given steel section for shear and for moment capacity. [04 Marks]
- Check the adequacy of the given steel section for deflection (see annex for deflection calculation formulae) and web bearing. Take $b_1 = 150 \text{ mm}$, $b_2 = 25 \text{ mm}$, and $n = 2 + \frac{0.6b_2}{k}$. [04 Marks]

Where $k = T + r$ for rolled I-sections. [04 Marks]

- Check the adequacy of the given steel section for web buckling. Take $\alpha_2 = 125 \text{ mm}$. [04 Marks]
- A 200 mm wide steel plate shown in Figure Q5B is subjected to tension and it is connected to another steel plate using 12 mm diameter bolts. Determine the effective net area (A_e) of the steel plate. The steel plate thickness (t) is 16 mm and $s_1 = 55 \text{ mm}$, $s_2 = 70 \text{ mm}$, $g_1 = 40 \text{ mm}$, $g_2 = 60 \text{ mm}$. [04 Marks]

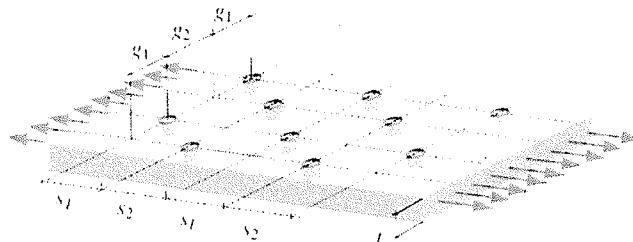
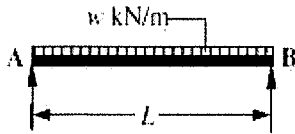
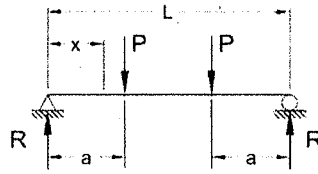


Figure Q5B





$$\text{Deflection at midspan} = \frac{5wL^4}{384EI}$$



$$\text{Deflection at midspan} = \frac{Pa}{24EI(3L^2 - 4a^2)}$$

Deflections at midspan due to different loadings

Table Q5 - Sectional Properties of UB 457 × 191 × 67 steel section

Section Designation	Mass per meter [kg/m]	Depth of section (D) [mm]	Width of section (B) [mm]	Thickness of web (t) [mm]	Thickness of Flange (T) [mm]	Root radius (r) mm	Depth between fillets (d) [mm]	Ratios for local buckling		Second moment of area		Radius of gyration	
								Flange (B/2T)	Web (d/t)	Axis x-x [cm ⁴]	Axis y-y [cm ⁴]	Axis x-x [cm]	Axis y-y [cm]
457x191x67	67.1	453.4	189.9	8.5	12.7	10.2	407.6	7.48	48	29380	1452	18.5	4.12
Section Designation	Elastic modulus		Plastic modulus		Buckling parameter (u)	Torsional index (x)	Warping constant (H) [dm ⁶]	Torsional constant (J) [cm ⁴]	Area of section [cm ²]	Indicative values for Advance275			
	Axis x-x [cm ³]	Axis y-y [cm ³]	Axis x-x [cm ³]	Axis y-y [cm ³]						M _{ex} [kNm]	P _{ey} for L _e =3.5 [kN]		
457x191x67	1296	153	1471	237	0.872	37.9	0.705	37.1	85.5	405	1460		