00100

THE OPEN UNIVERSITY OF SRI LANKA
Department of Civil Engineering
Bachelor of Technology (Civil) - Level 6

CEX6332 - Structural Design

FINAL EXAMINATION – 2012/2013

Time Allowed: **Four (04) Hours**

Date: 2013 - 08 - 21 (Wednesday) Time: 0930 - 1330 hrs.

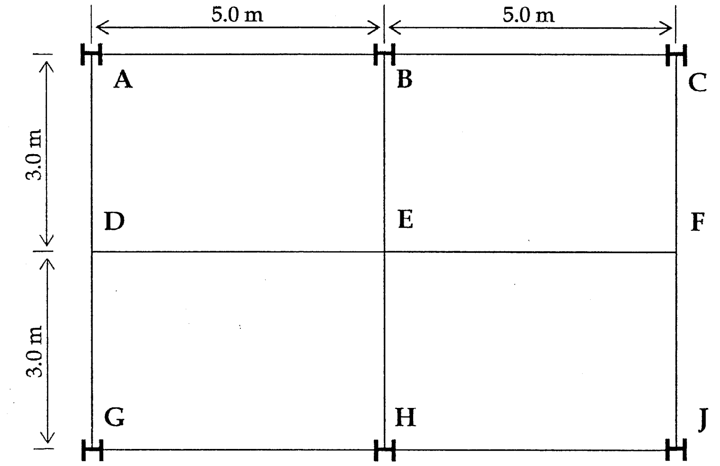
Paper consists of five (05) questions. Answer any four (04) questions.
You may use the booklet named **"Extracts From Relevant Standards"** provided to you with the course material, which also contain concrete design charts & steel sectional properties
You may assume and state reasonable values for any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

Q1.

The steel beams for part of the floor of a library with book storage are shown in the Figure 1 shown below. The floor is a reinforced concrete slab supported on universal beams.
The design loading has been estimated as:

Dead load—slab, self weight of steel, finishes, ceiling, partitions, services and fire protection: = 6.0 kN/m^2
Imposed load from Table I of BS 6399: Part 1 = 4.0 kN/m^2

Modulus of Elasticity of steel = 205 x 10^3 N/mm^2



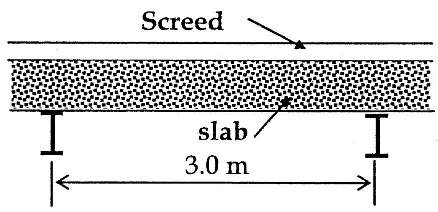


Figure 1

Section properties and beam analysis results are attached.

i.) Sketch the distribution of the floor loads to the two beams DE and BH, assuming two-way spanning slabs.
ii.) Calculate the service dead load and service imposed load acting on beam DE.
iii.) Calculate the factored shear force and factored moment acting on beam DE.
iv.) Using Grade S-275 steel, determine an economical universal beam section for beam DE.
v.) Show that the section selected for beam DE is satisfactory for deflection.
vi.) Calculate the service dead load and service imposed load acting on beam BH.
vii.) Calculate the factored shear force and factored moment acting on beam BH.
viii.) Using Grade S-275 steel, show that universal beam section 457 x 152 UB60 can be used for beam BH, satisfying moment capacity.
ix.) Check whether the shear capacity of the selected beam BH is adequate.
x.) Check whether the selected beam BH is satisfactory for deflection.

(25 marks)

Q2.

A rest house for pilgrims (Wishrama-shalawa) has been proposed to construct in Anuradhapura city. It is a two story masonry wall construction. The plan (one half of the building) and elevation of the building is shown in Figure 2. The overall length and width are 42.5m and 13m, respectively.

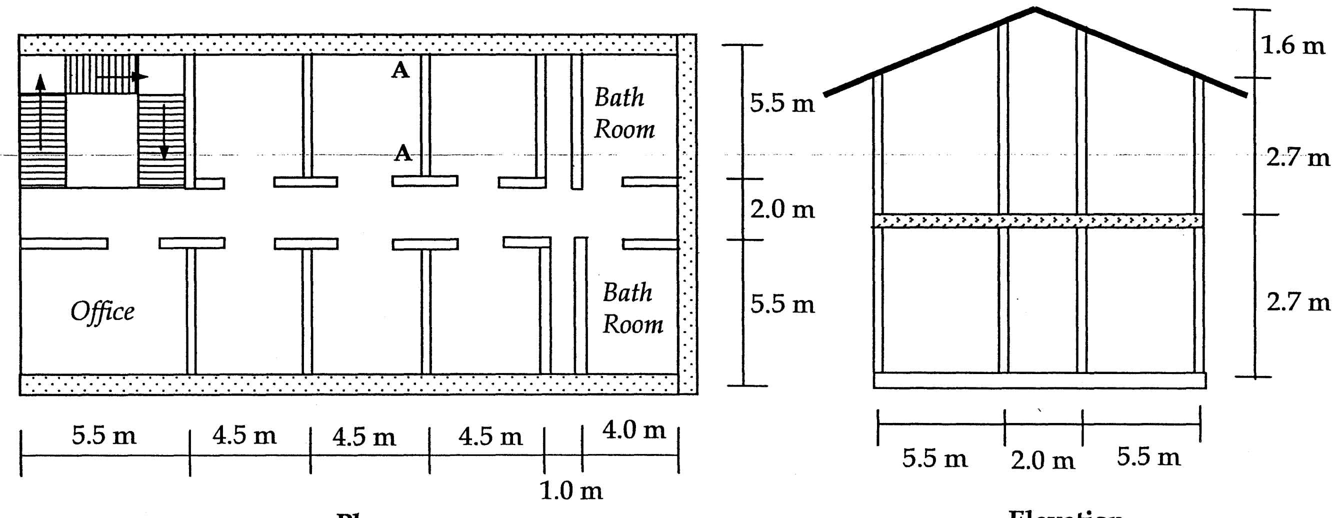


Figure 2: Proposed masonry building

Walls are constructed with locally made bricks and their dimensions are 200mm*100mm*50mm, length, breath, height, respectively. Half brick wall construction is 100mm, one brick wall construction is 210mm, one and half brick wall construction is 320mm. Further, wall thickness for ground and first floors are 350mm and 240mm, respectively. Indicate whatever your assumptions used clearly.

Loads	
Dead load of the roof (Plan area)	= 0.5 kN/m^2
Imposed load on the roof	= 0.25 kN/m^2
Imposed load on the floor	= 2.0 kN/m^2
Dead load by 150mm slab	= 3.6 kN/m^2
Dead load due to slab finishes	= 0.5 kN/m^2
No effect of wind load	
Geometry	
Thickness of floor slab	= 150mm
Floor to floor clear height	= 2.7m
Eave of the roof	= 1.0m

Weights of Materials	
Unit weight of RC	= 24.0 kN/m^2
Unit weight of masonry	= 18.0 kN/m^2
Mortar Designation	= IV
Compressive Strength of Brick	= 5.0 N/mm^2
γ_m	= 3.5
Water absorption	>12%

i.) Evaluate characteristic dead and live loads acting on the internal wall A-A in the ground floor level. (04 Marks)

ii.) Find different load combinations and corresponding design loads and eccentricities. (04 Marks)

iii.) Determine the slenderness ratio of the wall and compare with its permissible value. (03 Marks)

iv.) Check whether the internal wall is able to carry the design compressive load considering vertical load resistance of the wall. (03 Marks)

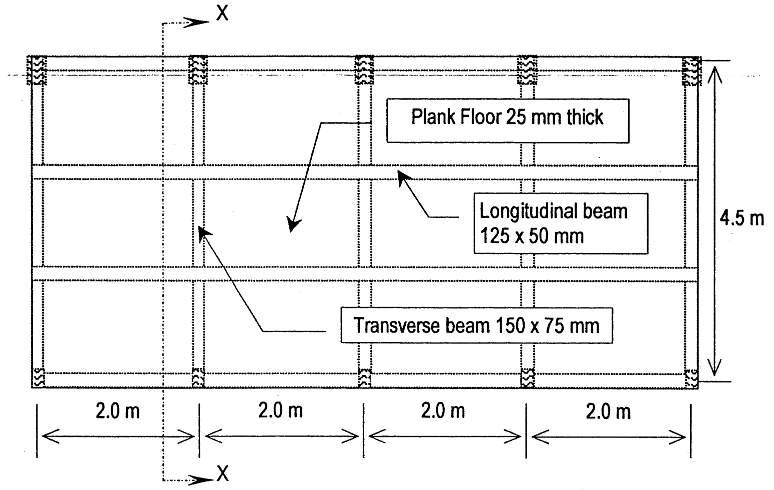
v.) Draw a figure showing boundary conditions for the external wall in 1st floor level office area. (04 Marks)

vi.) Determine the moments parallel and perpendicular to the bed joint if it is subjected a wind load of 0.50 kN/m^2. (04 Marks)

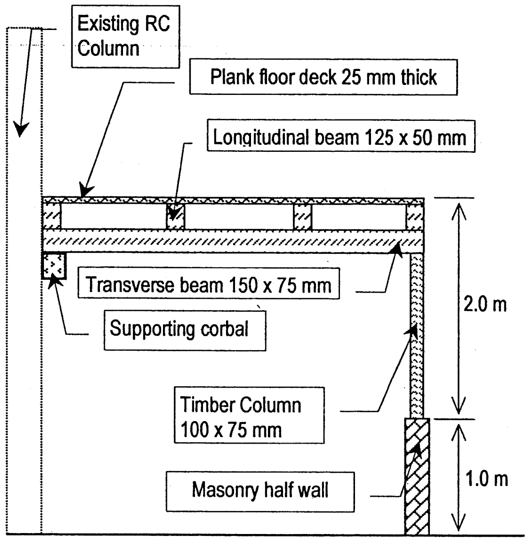
vii.) Check the safety of the external wall panel under the given wind load. (03 Marks)

Q3.

A section of the double height Civil Engineering Block 1 building at the CRC is to be provided with a timber mezzanine floor to accommodate a multimedia activity room for the students. The floor is to consist of a wodden plank decking supported by a timber beam framework as shown in Fig. 3, below. Transverse timber beams supported on corbals at one end and timber columns at the other carry the longitudinal timber beams connected to the decking. Structural dimensions and sectional sizes are given in the figures. The mezzanine floor is to be designed for an imposed load of 1.5 kN/m².



Plan of the Timber floor



Cross section X-X of the floor

Figure 3 – Plan & a Cross Section of the Mezzanine Floor

Strength Class D40 timber had been used for the fabrication. Dry exposure condtion with medium term loading had been assumed in the original design calculations. You are required to check the design of a critical longitudinal beam and a structural timber column according to BS 5268-1996.

<u>Section A</u> Use the following steps in checking adequacy of a longitudinal beam. You may aasume that longitudinal beams are simply supported.

i.) Evaluate the loading on the beam due to **live and dead** loads.

[02 marks]

ii.) Check the proposed beam against **lateral stability** criteria.

[01 marks]

iii.) Compute the applied **bending stress** at the critical section and check whether this is within the permissible limit.

[03 marks]

iv.) Check whether the **maximum allowable deflection** is within the permissible limit (0.003L).

[03 marks]

v.) Check whether the beam is safe against failure due to **shear.**

[03 marks]

vi.) Check whether applied **bearing stresses** at supports are within the permissible limit.

[03 marks]

<u>Section B</u> For checking a supporting column design, use the following steps.

i.) Evaluate the loading on the column due to **live and dead** loads as a <u>total axial load</u> and a <u>bending moment</u>. (You may neglect the load by the facia.)

[04 marks]

ii.) Compute the applied maximum **compressive stress** in the column and check whether this is within the permissible limit.

[03 marks]

iii.) Check the column for combined flexural and compressive stresses.

[03 marks]

Q4.

The design team for a dormitory decided on a structure in the form of a four storied building. Plan of the proposed building is given in the Figure 4 below. All grid beams support 200 mm thick full height masonry partition walls and their intersections are supported on columns.

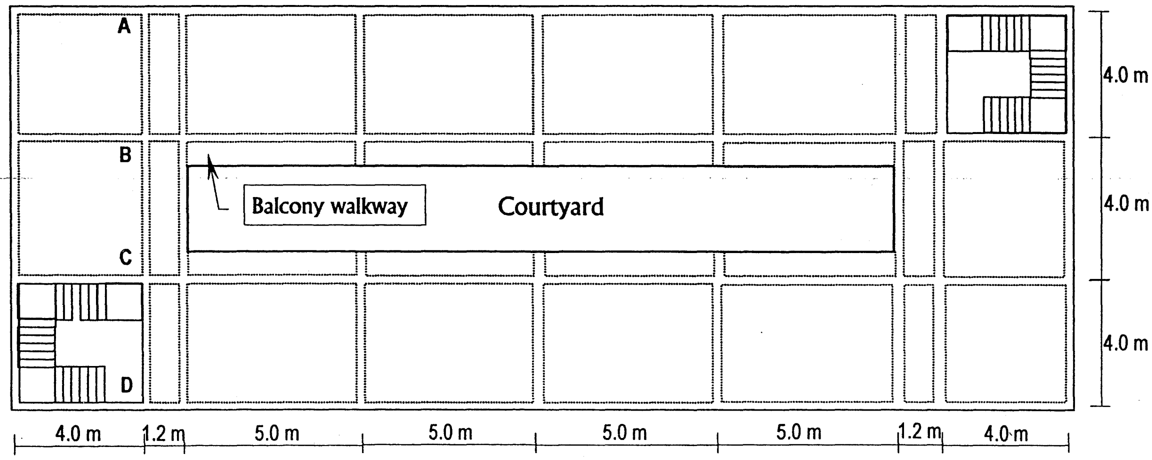


Figure 4 **Plan of the proposed building**

Loads on the structure;		**Strength of materials;**	
Dead load of the Roof	= 1.5 kN/m^2	Grade of concrete	= 30
Imposed load on the roof	= 0.8 kN/m^2	Characteristic strength of steel	
Imposed load on floors	= 3.5 kN/m^2	Main r/f	= 460 N/mm^2
** You may neglect the effects of Wind		Shear r/f	= 250 N/mm^2
Thickness of floor slab	= 125 mm	Condition of exposure	= Mild
Storey height (floor to floor)	= 3.0 m	Center to center dimensions are given for the grid	
		Order of floors – Ground, 1st, 2nd, 3rd	
Weights of materials			
Unit weight of RC	= 24.0 kN/m^3	Service stress = Design Stress / 1.5	
Unit weight of Masonry	= 18.0 kN/m^3	* Required design charts are provided *	

Using the above data, design the selected elements of the structure along following steps;

i.) Identify the critical slab panels for a upper floor slab and check whether a thickness of 125 mm is **adequate** for these panels based on **deflection criterion** only. You need not do any modifications. (You may assume that the slabs are continuous with the supporting beams & a suitable value for M/bd^2 for the expected loading).

(05 marks)

ii.) Evaluate the Characteristic and Design loads and tabulate Design **Bending moments** and **Shear forces** at **Critical sections** of the RC beam **ABC** (350 x 300 mm), assuming it to be continuous over the spans. (You may assume that the loads transferred to the beam are uniformly distributed along its span. Also, you may use the table with simplified factors given in the code. Neglect the effect of non symmetrical loading due to staircase.)

(05 marks)

iii.) Design reinforcement for the two spans of the above beam at critical sections to resist bending and shear forces. (Assume 16 mm bars for main reinforcement and 6 mm MS bars for shear reinforcement.) Curtail the beam reinforcement using simplified rules and sketch elevation and necessary cross sections in compliance with the standard method of detailing.

(06 marks)

iv.) Assuming the column at **B** (250 x 250), is **unbraced** and no bending moments are transferred from beams framing in to the column, evaluate **Critical Axial Load**, and the slenderness condition of the column segment between **2nd floor** and **3rd floor.**

(04 marks)

v.) Evaluate the **Design axial load** and generated **Bending moments** (if any), and design reinforcement for the column segment in section v.). Sketch elevation and required cross sections using the standard method of detailing.

(05 marks)

Q5.

Structural Engineers entrusted with the task of constructing an additional bridge alongside the existing one for the sole purpose of pedestrian traffic between CRC and the main campus (Figure 5a), have decided to design a prestressed girder for this purpose. The girder is to be prefabricated in a prestressing yard, transported to the site and placed over the abutments with the aid of a truck crane.

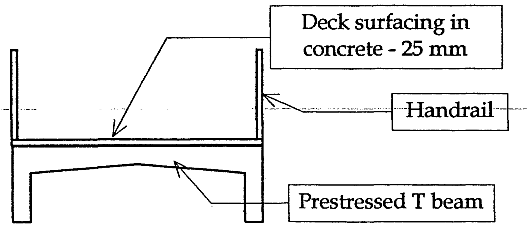


Figure 5a Bridge Deck Cross-section

A 3.0 kN/m² uniformly distributed load was assumed as the imposed load on the bridge. The bridge girder should be Pretensioned, Class 2, simply supported beam, with a 12.0 m span. It is to be applied with a 25 mm thick chip-concrete wearing surface and handrails using GI tubes attached using anchor bolts.

By preliminary calculations the section for the prestressed girder, material properties and the expected loading are given below in Figure 5b.

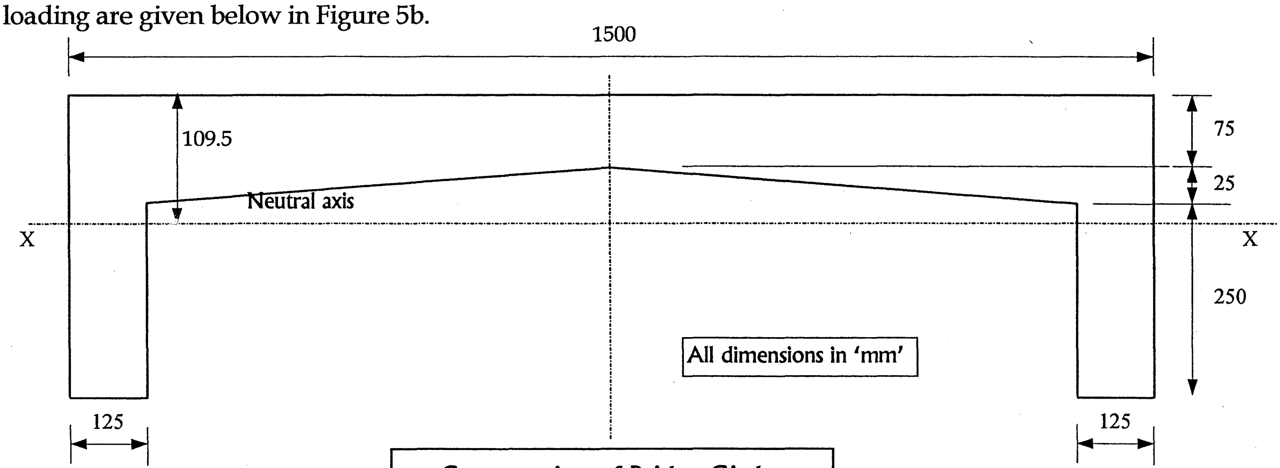


Figure 5b Cross-section of Bridge Girder

Strengths

f_{cu} at 28 days	= 50 MPa
f_{ci} at 7 days (transfer)	= 35 MPa
Transfer is 7 day after casting	
f_{pu} steel	= 1860 MPa
Sup. Stra. (11.3 mm) A_s	= 75 mm² /tendon
$f_{pi} = 0.7\ f_{pu}$	

Allowable concrete stresses for class 2 members

at transfer;

f'_{max}	= 17.5 MPa
f'_{min}	= - 2.7 MPa

at service;

f_{max}	= 16.7 MPa
f_{min}	= - 3.2 MPa

Loads

Unit weight of concrete	= 24 kN/m³
Unit weight surfacing	= 24 kN/m³
Imposed load on the deck	= 3.0 kN/m²

Loss of prestress

at transfer	= 7 %
at service	= 22 %

Concrete section properties

$A_c = 210.0 \times 10^3$ mm²

$I_{xx} = 2.04 \times 10^9$ mm⁴

You may use following inequalities (in standard notation) for your calculations

$Z_t \geq (\alpha M_s - \beta M_i) / (\alpha f_{max} - \beta f'_{min})$

$Z_b \geq (\alpha M_s - \beta M_i) / (\beta f'_{max} - \alpha f_{min})$

$P_i \geq (Z_t f'_{min} - M_i) / \alpha(Z_t/A_c - e)$ $\qquad e \leq (M_i - Z_t f'_{min}) / \alpha P_i + Z_t/A_c$

$P_i \leq (Z_b f'_{max} + M_i) / \alpha(Z_b/A_c + e)$ $\qquad e \leq (M_i + Z_b f'_{max}) / \alpha P_i - Z_b/A_c$

$P_i \leq (Z_t f_{max} - M_s) / \beta (Z_t/A_c - e)$ $\qquad e \geq (M_s - Z_t f_{max}) / \beta P_i + Z_t/A_c$

$P_i \geq (Z_b f_{min} + M_s) / \beta (Z_b/A_c + e)$ $\qquad e \geq (M_s + Z_b f_{min}) / \beta P_i - Z_b/A_c$

Using the given data, design this prestressed girder along the following steps;

i.) Evaluate the dead and imposed loads on the beam at transfer and in service and calculate the critical bending moments at the two instances. Assume that the beam is kept in the same orientation at casting and in service.

[05 marks]

ii.) Check the adequacy of the <u>section</u> in carrying the stresses at **transfer** and in **service**.

[05 marks]

iii.) Determine the range of prestress force required at the mid span of the beam assuming tendon centroid eccentricity of 120 mm from the **Nutral Axis** of the section.

[05 marks]

iv.) Suggest the minimum possible number of tendons (corresponding initial prestress force) and sketch a suitable physical arrangement for them (Assume $f_{pi} = 0.7\ f_{pu}$).

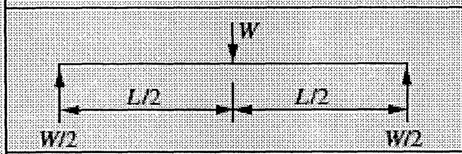
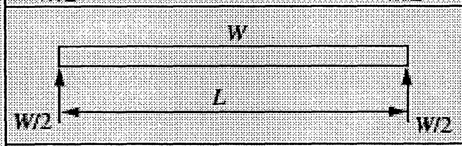
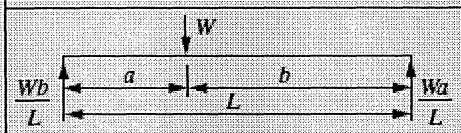
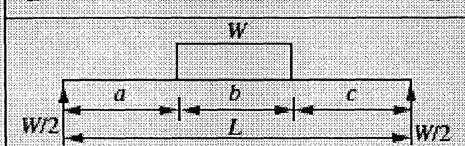
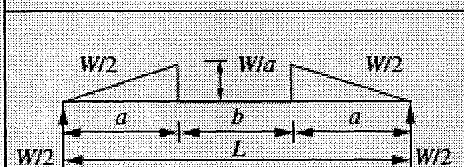
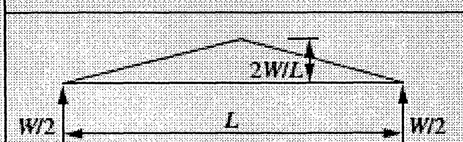
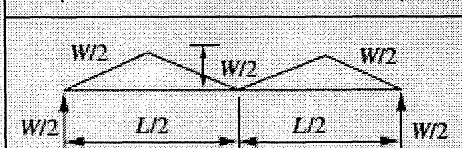
[05 marks]

v.) Check whether the prestress force calculated above allows for same location of tendon centroid at the supports of the beam (In other words check whether straight tendons could be used without debonding). If debonding has to be carried out, evaluate how many tendons should be debonded at the supports so that straight tendons could be used.

[05 marks]

For question Q1.

Simply supported beam maximum moments and deflections

Beam and load	Maximum moment	Deflection at centre
	WL/4	$\frac{WL^3}{48EI}$
	WL/8	$\frac{5WL^3}{384EI}$
	Wab/L	$\frac{WL^3}{48EI}\left[\frac{3a}{L}-4\left(\frac{a}{L}\right)^3\right]$
	W(a/2+b/8)	$\frac{W}{384EI}[8L^3-4Lb^2+b^3]$
	Wa/3	$\frac{Wa}{120EI}[16a^2-20ab+5b^2]$
	WL/6	$\frac{WL^3}{60EI}$
	WL/8	$\frac{WL^3}{73.14EI}$

UNIVERSAL BEAM

Designation		Depth of section D	width of section B	Thickness		Root radius	Depth Between Filters	Rations For Local Bucking		Second Moment of Area		Radius of Gyration		Elastic Modulus		Plastic Modulus		Buckling parameter	Torsional Index	Wrapping Constant H	Torsional Constant J	Area of section A
Serial size	Mass per m			Web t	Flange T	r	d	Flange b/T	Web d/T	Axis x-x	Axis y-y	Axis x-x	Axis y-y	Axis x-x	Axis y-y	Axis x-x	Axis y-y	μ	x			
mm	Kg	mm	mm	mm	mm	mm	mm													cm^6	cm^4	cm^2
457x152	82	465.1	153.5	10.7	18.9	10.2	407.0	4.06	38.0	36 200	1140	18.6	3.31	1560	149	1800	235	0.872	27.3	0.569	89.3	104
	74	461.3	152.7	9.9	17.0	10.2	407.0	4.49	41.1	32 400	1010	18.5	3.26	1410	133	1620	209	0.87	30.0	0.499	66.6	95.0
	67	457.2	151.9	9.1	15.0	10.2	407.0	5.06	44.7	28 600	878	118.3	3.21	1250	116	1440	182	0.867	33.6	0.429	47.5	85.4
	60	454.7	152.9	8.0	13.3	10.2	407.0	5.75	51.0	25 500	794	18.3	3.23	1120	104	1280	163	0.869	37.5	0.387	33.6	75.9
	52	449.8	152.4	7.6	10.9	10.2	407.0	6.99	53.6	21 300	645	17.9	3.11	949	84.6	1090	133	0.859	43.9	0.311	21.3	66.5
406x178	74	412.8	179.7	9.7	16.0	10.2	360.5	5.62	37.2	27 300	1540	17.0	4.03	1320	172	1500	267	0.881	27.6	0.608	63.0	95.0
	67	409.4	178.8	8.8	14.3	10.2	360.5	6.24	41.0	24 300	1360	16.9	4.00	1190	153	1350	237	0.88	30.5	0.533	46.0	85.5
	60	406.4	177.8	7.8	12.8	10.2	360.5	6.95	46.2	21 500	1200	16.8	3.97	1060	135	1190	208	0.88	33.9	0.464	32.9	76.0
	54	402.6	177.6	7.6	10.9	10.2	360.5	8.15	47.4	18 600	1020	16.5	3.85	925	114	1050	177	0.872	38.5	0.39	22.7	68.4
406x140	46	402.3	142.4	6.9	11.2	10.2	359.7	6.36	52.1	15 600	539	16.3	3.02	778	75.7	888	118	0.87	38.8	0.206	19.2	39.0
	39	397.3	141.8	6.3	8.6	10.2	359.7	8.24	57.1	12 500	411	15.9	2.89	627	58.0	721	91.1	0.859	47.4	0.155	10.6	49.4
356x171	67	364.0	173.2	9.1	15.7	10.2	312.3	5.52	34.3	19 500	1360	15.1	3.99	1070	157	1210	243	0.887	24.4	0.413	55.5	85.4
	57	358.6	172.1	8.0	13.0	10.2	312.3	6.62	39.0	16 100	1110	14.9	3.92	896	129	1010	199	0.884	28.9	0.331	33.1	72.2
	51	355.6	171.5	7.3	11.5	10.2	312.3	7.46	42.8	14 200	968	14.8	3.87	796	113	895	174	0.882	32.2	0.286	23.6	64.6
	45	352.0	171.0	6.9	9.7	10.2	312.3	8.81	45.3	12 100	812	14.6	3.78	687	95.0	774	147	0.8750	36.9	0.238	15.7	57.0
356x127	39	352.8	126.0	6.5	10.7	10.2	311.2	5.89	47.9	10 100	357	14.3	2.69	572	56.6	654	88.7	0.872	35.3	0.104	14.9	49.4
	33	348.5	125.4	5.9	8.5	10.2	311.2	7.38	52.7	8200	280	14.0	2.59	471	44.7	540	70.2	0864	42.2	0.081	8.68	41.8
305x165	54	310.9	166.8	7.7	13.7	8.9	265.7	6.09	34.5	11700	1060	13.1	3.94	753	127	845	195	0.89	23.7	0.234	34.5	68.4
	46	307.1	165.7	6.7	11.8	8.9	265.7	7.02	39.7	9950	897	13.0	3.90	648	108	723	166	0.89	27.2	0.196	22.3	58.9
	40	3.3.8	165.1	6.1	10.2	8.9	265.7	8.09	43.6	8520	763	12.9	3.85	561	92.4	624	141	0.888	31.1	0.164	14.7	51.5
305x127	48	310.4	125.2	8.9	14.0	8.9	264.6	4.47	29.7	9500	460	12.5	2.75	612	73.5	706	116	0.874	23.3	0.101	31.4	60.8
	42	306.6	124.3	8.0	12.1	8.9	264.6	5.14	33.1	8140	388	12.4	2.70	531	62.5	610	98.2	0.872	26.5	0.0842	21.0	53.2
	37	303.8	123.5	7.2	10.7	8.9	264.6	5.77	36.7	7160	337	12.3	2.67	472	54.6	540	85.7	0.871	29.6	0.0724	14.9	47.5
305x102	33	312.7	102.4	6.6	10.8	8.9	275.9	4.74	41.8	6490	193	12.5	2.15	415	37.8	480	59.8	0.866	31.7	0.0111	12.1	41.8
	28	308.9	101.9	6.1	8.9	8.9	275.9	5.72	45.2	5420	157	12.2	2.08	351	30.8	407	48.9	0.858	37.0	0.0353	7.63	36.3
	25	304.8	101.6	5.8	6.8	8.9	275.9	7.47	47.6	4390	120	11.8	1.96	288	23.6	338	38.0	0.844	43.8	0.0266	4.65	31.4
254x146	43	259.6	147.3	7.3	12.7	7.6	218.9	5.80	30.0	6560	677	10.9	3.51	505	92.0	568	141	0.889	21.1	0.103	24.1	55.1
	37	256.0	146.4	6.4	10.9	7.6	218.9	6.72	34.2	5560	571	10.8	3.47	434	78.1	485	120	0.889	24.3	0.0858	15.5	47.5
	31	251.5	146.1	6.1	8.6	7.6	218.9	8.49	35.9	4440	449	10.5	3.35	353	61.5	396	94.5	0.879	29.4	0.0662	8.73	40.0
254x102	28	260.4	102.1	6.4	10.0	7.6	225.1	5.10	35.2	4010	178	10.5	2.22	308	34.9	353	54.8	0.873	27.5	0.0279	9.64	36.2
	25	257.0	101.9	6.1	8.4	7.6	225.1	6.07	36.9	3410	148	10.3	2.14	265	29.0	306	45.8	0.864	31.4	0.0228	6.45	32.2
	22	254.0	101.6	5.8	6.8	7.6	225.1	7.47	38.8	2870	120	10.00	2.05	226	23.6	262	37.5	0.854	35..9	0.0183	4.31	28.4
203x133	30	206.8	133.8	6.3	9.6	7.6	172.3	6.97	27.3	2890	384	8.72	3.18	279	57.4	313	88.1	0.882	21.5	0.0373	10.2	38.0
	25	203.2	133.4	5.8	7.8	7.6	172.3	8.55	29.7	2360	310	8.54	3.10	232	46.4	260	71.4	0.876	25.4	0.0295	6.12	32.3
203x102	23	203.2	101.6	5.2	9.3	7.6	169.4	5.46	32.6	2090	163	8.49	2.37	206	232	232	49.5	0.89	22.6	0.0153	6.87	29.0
178x102	19	177.8	101.6	4.7	7.9	7.6	146.8	6.43	31.2	1360	138	7.49	2.39	153	27.2	171	41.9	0.889	22.6	0.00998	4.37	24.2
152x89	16	152.4	88.9	4.6	7.7	7.6	121.8	5.77	26.5	838	90.4	6.40	2.10	110	20.3	124	31.4	0.889	19.5	0.00473	3.61	20.5
127x76	13	127.0	76.2	4.2	7.6	7.6	96.6	5.01	23.0	477	56.2	5.33	1.83	75.1	14.7	85	22.7	0.893	16.2	0.002	2.92	16.8

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