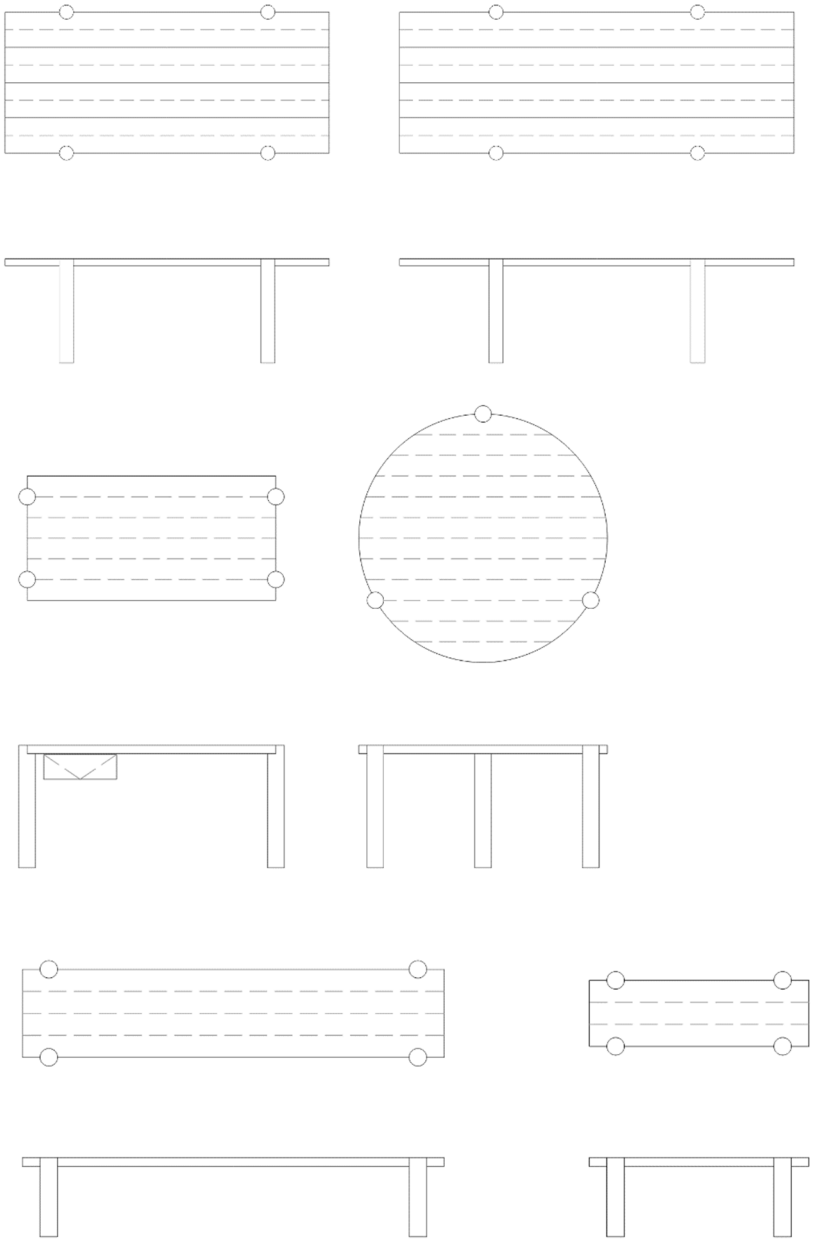
professor max irvine engineers



Skupa Tables and Benches Structural Analysis Report

8 March 2021

Revision A

Prepared by	Reviewed by	Status	Revision	Date
WW	MG	For review	A	8/3/21

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Introduction

The purpose of this report is to summarise the strength, stability and structural adequacy of the current design of the Skupa Short Rectangular Table, Long Rectangular Table, Desk, Long Bench, Short Bench and Round Table. The following design drawings were used for the calculations:

- Long Bench Rev F
- Circular Rev A
- Desk Rev A
- Table Rev B

Assumptions

Material assumptions

Material	Density (kg/m3)	Modulus of Elasticity (GPa)	Yield Stress (MPa)	Ultimate Tensile Strength (MPa)	Thermal Expansion Coefficient
Steel	7800	200	250	440	7.2 x 10 -6 / °C

	Assumed F grade	Density (kg/m3)	Modulus of Elasticity (GPa)	Joint group	f'b (MPa)	f't (MPa)	f'c (MPa)
American Oak/Walnut	F17 seasoned	750 (Oak) 615 (Walnut)	14	JD2	42	25	34

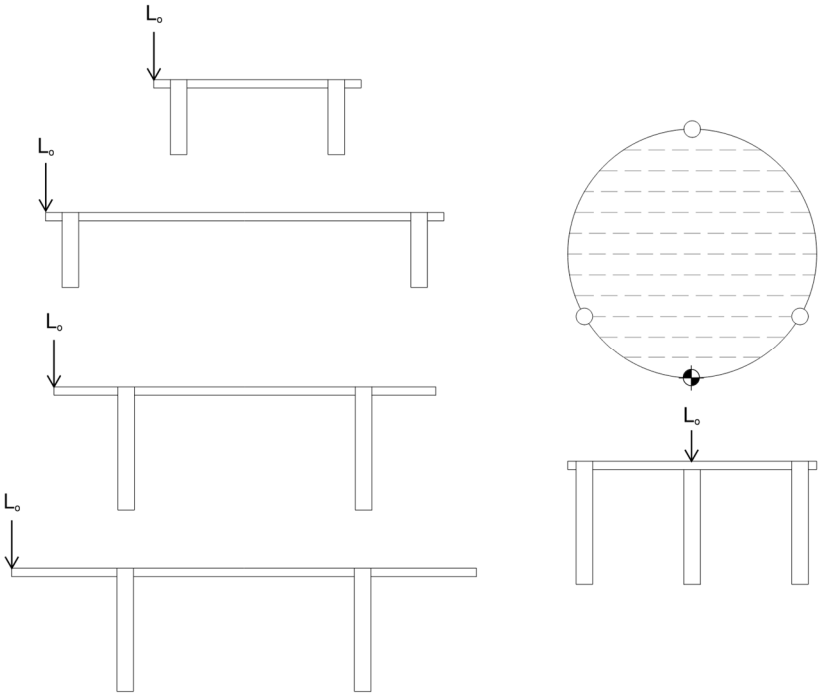
Load Assumptions

The following load cases were considered for each element, with standard cases as recommended in AS-NZS 4442-2018, AS 4688.1-2018 and AS 4688.1-2000 as well as extreme ultimate load cases. Since there are no test levels for tables, we will assume similar test levels for seating as a conservative load case.

Element	**Loading**
Skupa Tabletops	1) 160kg static central point load (Test Level 4) 2) 200kg static central point load (Test Level 6) 3) 2kPa uniform loading (equivalent to domestic floor loading) 4) 76kg leg forward static load (Test Level 5, 6) 5) 76kg leg sideways static load (Test Level 5, 6) 6) Table tipped at 45 degree angle from ground (leg lateral loading test)
Skupa Benches	1) 160kg static central point load (Test Level 4) 2) 200kg static central point load (Test Level 6) 3) 76kg leg forward static load (Test Level 5, 6) 4) 76kg leg sideways static load (Test Level 5, 6)

Analysis Results

Overturning stability



Item	Overturning load L_o American Oak (kg)	Overturning load L_o Walnut (kg)
Long Rectangular Table	147	120
Short Rectangular Table	205	168
Long Bench	605	496
Short Bench	176	144
Round Table	103	85

Lateral leg loading 76kg

It was assumed the lateral loads are applied at the top of each bench/table and is resisted by 2 table/bench legs, and connections are tight and rigid.

Item	Lateral deflection (mm)
Long Rectangular Table	3.8
Short Rectangular Table	3.8
Desk	4.2
Long Bench	2.4
Short Bench	1.4
Round Table	3.8

A maximum moment of 0.28kNm was obtained in the large table legs. The current connection has a maximum moment capacity of 0.38kNm, equivalent to a 100kg lateral load.

The leg connections were also analysed for a conservative worst-case lateral load when the tables are tipped at 45 degrees to the ground – the lateral load created by this load case is approximately 10% larger than the 76kg lateral load case for the long rectangular table, and satisfies the lateral capacity of the timber legs.

Static Vertical Loading

160kg Static Load Test

Item	Maximum bending stress (MPa)	Structural Adequacy	Vertical Deflection (mm)
Long Rectangular Table	2.3	OK	1
Short Rectangular Table	2.4	OK	1
Desk	3.0	OK	1.4
Long Bench	5.2	OK	5.6 (span/375)
Short Bench	2.7	OK	0.6
Round Table	1.9	OK	0.6

200kg Static Load Test

Item	Maximum bending stress	Structural Adequacy	Deflection
Long Rectangular Table	2.9	OK	1.2
Short Rectangular Table	3.0	OK	1.3
Desk	3.8	OK	1.7
Long Bench	6.4	OK	6.9 (span/304)
Short Bench	3.3	OK	0.65
Round Table	2.3	OK	0.7

Worst case deflections were present in the long bench, and deemed to be acceptable (below the general span/300 ratio for serviceability)

Leg to Top Connection Check

Two typical connection types were analysed for the project. One connection through the side grain of the timber (tables and benches), and one through the end grain (desk). The following connection detail was assumed.

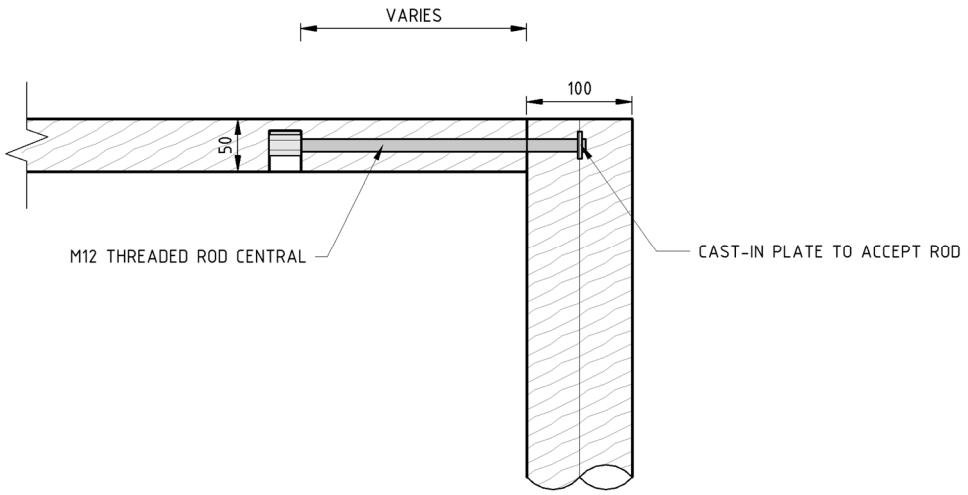


Figure 1: Current assumed connection

The timber connections were checked in accordance with AS1720.1 – Timber Structures. While the code does not prescribe a specific check for bolted connections within timber end grain, we can conservatively assume the capacity of the largest diameter nail loaded in single side shear (6mm dia) with a 0.6 reduction factor used for end grain connections.

Shear Failure Load through side grain – applies to rectangular tables and benches (kg)	340
Shear Failure Load through end grain – applies to round table and desk (kg)	200

It is recommended a rubber washer or similar is used for the internal nut connection to provide some tension to the rod and prevent any loosening of the leg due to vibrations and lateral loading.

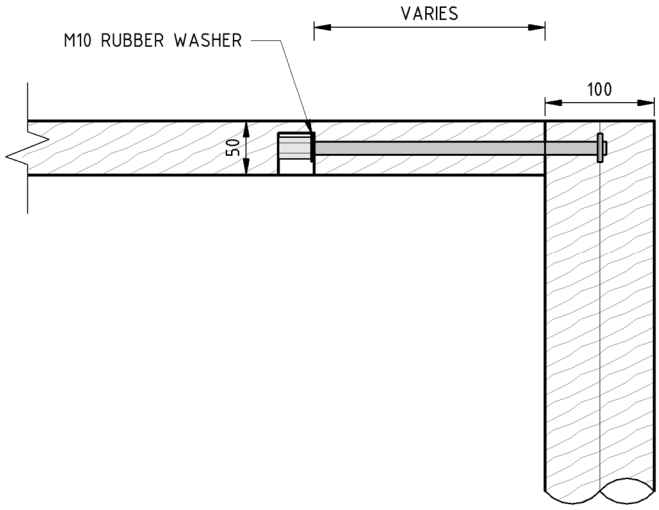


Figure 2: Proposed modified connection

Tabletop Plank Connection Check

The threaded rod connections between the intermediate boards for the tables are expected to perform in a similar manner to the leg connection. Since the boards are oriented with the threaded rods connecting through side grain only, the expected failure load of a single M12 threaded rod tie between boards is 340kg. Gaps created by installation are not expected to become an issue structurally – the threaded rods will perform adequately under a 200kg vertical load even with a 5mm gap.

Bearing Pad Check

For a bearing pad of 40mm diameter, a maximum 200kg point load plus 25kg will create a maximum bearing pressure of 1.8MPa which is not expected to create any permanent deformation in support structure below.

Thermal Performance

Thermal expansion and contraction are not expected to affect the structural performance of the Skupa furniture if the timber is adequately seasoned. Tolerances of the threaded rod holes should account for some differential thermal movement (~0.5mm)

Safety Factor

Structurally it is recommended a safety factor of 1.5 be adopted for maximum loading on the furniture elements to account for manufacturing and installation tolerances, as well as future installation errors if the furniture is moved.

Overturning loads are based on geometry only and less reliant on connections and variance in material properties, so a lower safety factor of 1.1 has been applied to these results.

Results Summary

The current design of the Skupa tables, desk and benches are structurally adequate and typically satisfy an equivalent Level 6 Seating Test Level, as well as a 2kPa uniform loading (equivalent to a residential balcony floor load). The exception is the desk and round table, limited by the end grain connection at the leg which is expected to fail if a 200kg point load is applied directly adjacent to the leg.

Skupa Furniture	**Failure load (kg)**	**Maximum safe working load SF=1.5 (vertical failure loads) SF=1.1 (overturning) (kg)**
Long Rectangular Table	>600kg Central Point Load 340kg Point Load adjacent leg 147kg Edge Point Load (overturning)	400kg Central Point load 225kg Point Load adjacent leg 130kg Edge Point Load
Short Rectangular Table	>600kg Central Point Load 340kg Point Load adjacent leg 205kg Edge Point Load (overturning)	400kg Central Point load 225kg Point Load adjacent leg 185kg Edge Point Load
Desk	>600kg Central Point Load 200kg Point Load adjacent leg Overturning not critical	400kg Central Point load 130kg Point Load adjacent leg
Long Bench	>600kg Central Point Load 340kg Point Load adjacent leg Overturning not critical	400kg Central Point load 225kg Point Load adjacent leg
Short Bench	>600kg Central Point Load 340kg Point Load adjacent leg 176 kg Edge Point Load (overturning)	400kg Central Point load 160kg Point Load adjacent leg
Round Table	600kg Central Point Load 200kg Point Load adjacent leg 103 kg Edge Point Load (overturning)	400kg Central Point load 130kg Point Load adjacent leg 93kg Edge Point Load (overturning)

It is recommended a rubber washer or similar is used for the internal nut connection to provide some tension to the rod and prevent any loosening of the leg due to vibrations and lateral loading.