Flexural Capacity of MultiPole Piles and MultiPole Connectors for Piles Subjected to Short Duration Loading – 2nd Edition

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1. Introduction

This submission presents design charts for determining the flexural capacity of MultiPole piles and splice joints using MultiPole Connectors for both normal and high density round timber piles.

For all applications specific geotechnical advice should be obtained.

2. Structural Analysis

Structural analysis and design conforms to the following standards:

NZS 1170 [1] New Zealand Standard: Structural Design Actions.

NZS 3603:1993 [2] New Zealand Standard: Timber Structures.

Key assumptions are:

- Short-duration load combinations are applicable.
- The soil provides continuous lateral restraint to the MultiPole pile preventing buckling. If the site conditions are such that a section of the pile is unrestrained due to weak or liquefiable sub-soil then the MultiPole pile should be considered a column with a stability modification factor k8 applied to the unrestrained length. Note that a k8 factor does not apply to the MultiPole Connector capacity.
- The MultiPoles can be SED (machine peeled, naturally tapered), Uglies (debarked, naturally tapered) or UniLog (machined, uniform diameter).
- The moment capacity of the MultiPole piles, is determined assuming that the timber is wet with reduction factors included for steaming and machine shaving according to NZS3603:1993.
- Two contributions to flexural capacity at pile splices are considered: the moment capacity due to the axial load on the pile; and the moment capacity of the MultiPole Connector.
- Reinforcing bars, which may be grouted into the pile core to provide tension capacity across the splice joint, are considered to be de-bonded at the connector locations and therefore do not contribute to the moment capacity of the splice.

The following material properties are considered for the piles:

Density	Bending strength (MPa)	Compression strength (MPa)	Tension strength (MPa)
High	37.6	22.5	22.4
Normal	27.5	14.4	16.6

3. Flexural capacity of the piles

The maximum moment that can be applied to round timber is a function of the size of the section, the material properties and the axial stresses within the section.

An interactive design process identifies the moment capacity of the pile, ϕM_p, as a function of the applied axial load, N*. The steps for this design process are:

Step 1: Calculate the expected axial force on the pile, N.*
The axial force on the pile is applied by the superstructure and foundation self-weight for earthquake or wind load combinations.

Step 2: Choose a pile diameter and density.
The small end diameter (SED) of a pile can vary from 175 to 600mm. Generally, piles less than 250mm SED are normal density, while piles greater than 250mm SED are generally available as high density.

Step 3: Determine the axial stress within the pile
From the applied axial force, N*, determine the axial stress in the pile:

$$\frac{N^*}{A} = \frac{N^*}{\frac{\pi}{4} D^2}$$

Where: D = the pile diameter;
A = the area of the pile.

Step 4: Determine the axial capacity ratio
Using the axial stress (N* / A), the axial capacity ratio ($N^*/\phi N_n$) can be determined from Figure 1a.

Step 5: Determine the design moment capacity ratio
Using the axial capacity ratio ($N^*/\phi N_n$), the moment capacity ratio ($\phi M_p / Z$) is determined from Figure 1b.

Step 6: Calculate the design moment capacity
Using the design moment ratio ($\phi M_p / Z$), the design moment can be determined:

$$\phi M_p = \frac{\phi M_p}{Z} Z = \frac{\phi M_p}{Z} \frac{\pi}{32} D^3$$

Where: Z = the section modulus of the pile.

Step 7: Check that the applied moment is less than the design moment capacity

$M^* \leq \phi M_p$

If the applied moment, M*, is greater than the design moment capacity, ϕM_p, then return to step 2 and re-work using a larger diameter pile.

4. Flexural capacity of splice joints with MultiPole connectors

Two contributions to flexural capacity of the splices are considered: the moment capacity due to axial-load on the pile; and the moment capacity of the MultiPole Connector.

As moment is applied to the splice joint the axial-load on the pile becomes eccentric to the centre of compression applied by the timber, thus providing a restoring moment. The restoring moment is calculated at the point that the extreme compression fibre at the joint reaches the timber characteristic compressive stress.

Cement grout within the core of the MultiPole pile prevents local buckling of the steel tube connector enabling the full plastic section capacity to be achieved. Due to the high strain capability of the steel section, it is assumed that the plastic moment capacity from the steel section and the moment capacity due to axial-load on the splice occur simultaneously.

An interactive design process is used to identify the design moment capacity of the splice, ϕM_s, as a function of the applied axial load, N*. The steps for this design process are listed below:

Step 1–4: See section 3.

Step 5: Determine the design moment capacity ratio due to axial load

Using the axial capacity ratio ($N^*/\phi N_n$), calculated in step 4, the design moment capacity ratio due to axial load on the splice join ($\phi M_a/Z$) can be determined from Figure 2. Note, only compressive axial load on the pile provides a restoring moment to the splice joint.

Therefore, for tension loads on the pile:

$$(\phi M_a / Z) = 0$$

Step 6: Calculate the design moment capacity due to axial load

Using the design moment ratio ($N^*/\phi N_n$), the design moment of the splice joint due to axial load can be determined:

$$\phi M_a = \frac{\phi M_a}{Z} Z = \frac{\phi M_a}{Z} \frac{\pi}{32} D^3$$

Step 7: Determine the design moment capacity of the MultiPole Connector

Certain outside diameters for MultiPole Connectors have been allocated for use with certain MultiPole SED's (see Table 1 and 2). The plastic section design moment capacity of the MultiPole Connector is given in Tables 1 and 2 for both thin and thick walled tubes respectively.

From Table 1 or 2, choose a MultiPole Connector that corresponds to the SED of the MultiPole and read off the moment capacity of the MultiPole Connector; ϕM_c. MultiPole Connectors are designed to be sufficiently embedded into the piles to develop their moment capacity. Table 1b and 2b give the minimum total length of each MultiPole Connector. Bursting stresses applied to the pile by the connector are limited to the tensile strength of the timber [3].

It is important to note that the full plastic section moment capacity can only be considered if the hollow core of the MultiPole is grouted. If the MultiPole is not grouted, local buckling or tolerances may reduce the moment capacity achieved by the MultiPole Connector.

It is also assumed that either ASTM106 Grade B or API5L Grade B pipe is used for the connector with a characteristic yield stress of 241MPa. Other grades of steel can be used for the MultiPole Connectors but the moment capacity and connector length must be recalculated (and the values in Table 1 and 2 must not be used).

Step 8: Sum the design moment capacity due to axial load and the MultiPole Connector

The design moment capacity of the splice joint, ϕM_s, is the sum of the moment capacity due to axial load, ϕM_a, and the moment capacity of the connector, ϕM_c,:

$$\phi M_s = \phi M_a + \phi M_c$$

Step 9: Check that the applied moment is less than the design moment capacity

$$M^* \leq \phi M_s$$

If the applied moment, M*, is greater than the moment capacity, ϕM_s, return to Step 2 and re-work using a larger diameter MultiPole or return to Step 7 and use a thicker walled MultiPole Connector.

5. Axial capacity of splice joints

If MultiPole pile splice joints are subjected to tension, a reinforcing bar can be grouted within the pile to provide tension capacity. Sufficient cover concrete shall be provided between the reinforcing bar and the internal diameter of the MultiPole pile to ensure adequate durability. Refer to Table 3 for recommended bar sizes.

The design axial tension capacity of reinforcing bars, ϕN_t, for grade 300 and 500 steel is given in Table 4. The axial tension capacity of the specified rod must be greater than the absolute tensile axial demand, N_t^*:

$$N_t^* \leq \phi N_t$$

6. Disclaimer

The design method presented is for determining the flexural capacity of MultiPole piles and splice joints in MultiPole piles for both normal and high density timber rounds under the application of short duration loads. If all the design assumptions listed above are not appropriate for a given application then this design guide should not be used.

For all applications specific geotechnical advice should be obtained.

7. References

1. NZS1170. Structural Design Actions, New Zealand Standards, Wellington.
2. NZS3603. (1999). Timber Structures Standard, New Zealand Standards, Wellington.
3. Ardalany, M., Deam, B., Fragiacomo, M., and Crews, K. I. "Tension perpendicular to grain strength of wood, Laminated Veneer Lumber (LVL) and Cross banded LVL (LVL_C)." 21st Australasian conference on the mechanics of structures and materials, Melbourne, Victoria, Australia, pp. 6.

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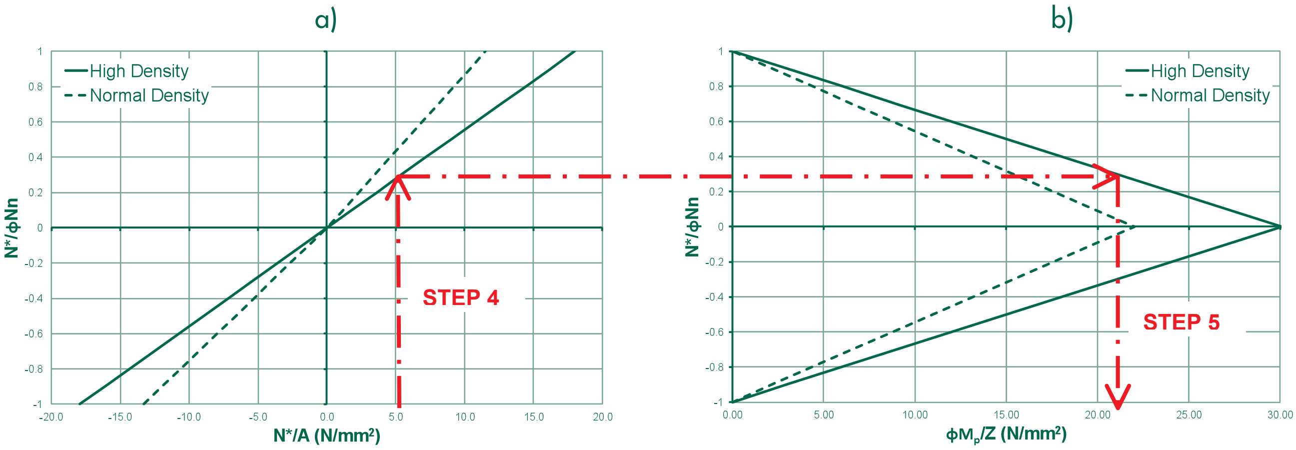

Figure 1. Axial force-moment interaction charts for MultiPoles. a) Axial capacity ratio. b) Flexural capacity ratio

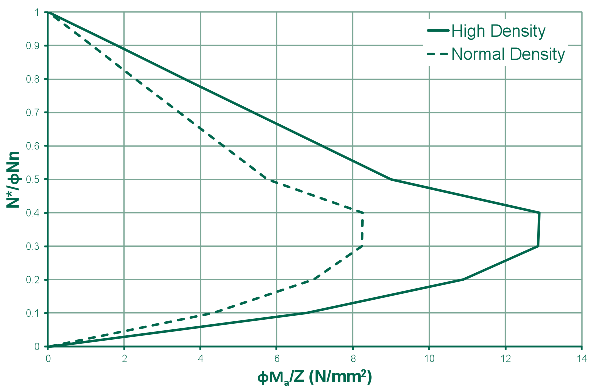

Figure 2. Axial force-moment interaction chart for MultiPole splice joint

Table 1a. Design moment capacity and length for thin wall MultiPole Connectors

MultiPole SED (mm)	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600
ΦMc (kN.m)	1.6	2.7	2.7	5.2	5.2	8.3	8.3	8.3	15.3	15.3	15.3	25.8	25.8	25.8	25.8	25.8	25.8	25.8	25.8
Connector Code	MPC50L	MPC63L		MPC76L		MPC93L			MPC118L			MPC146L							

Table 1b. Properties of thin wall MultiPole Connectors

Code	MultiPole core diameter (ømm)	Connector OD (ømm)	Connector wall thickness(mm)	Connector length(mm)
MPC50L	50	48.3	3.68	400
MPC63L	63	60.3	3.90	400
MPC76L	76	73.0	5.16	500
MPC93L	93	88.8	5.49	600
MPC118L	118	114.3	6.02	700
MPC146L	146	141.3	6.55	800

Table 2a. Design moment capacity and length for thick wall MultiPole Connectors

MultiPole SED (mm)	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600
ΦMc (kN.m)	2.1	3.6	3.6	6.6	6.6	11.0	11.0	11.0	20.8	20.8	20.8	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0
Connector Code	MPC50H	MPC63H		MPC76H		MPC93H			MPC118H			MPC146H							

Table 2b. Properties of thick wall MultiPole Connectors

Code	MultiPole core diameter (ømm)	Connector OD (ømm)	Connector wall thickness(mm)	Connector length(mm)
MPC50H	50	48.3	5.08	400
MPC63H	63	60.3	5.54	500
MPC76H	76	73.0	7.01	600
MPC93H	93	88.8	7.62	700
MPC118H	118	114.3	8.56	800
MPC146H	146	141.3	9.53	1000

Table 3. Maximum diameters for deformed reinforcing bars

MultiPole Diameter (mm)	150	175	200	225	250	275	300	325	350–600
Max. Bar Diameter (mm)	10[3]	12[3]	12[3]	12 or 16[3]	12 or 16[3]	32	32	32	40

Note:
1. Concrete compressive strength is assumed to be not less than 25 MPa.
2. A minimum cover of 30mm has been assumed for a 50 year intended life.
3. Recommended to be Hot Dip Galvanised

Table 4. Maximum tension capacity for reinforcing bar

Bar Diameter (mm)	10	12	16	20	25	32	36	40
ΦNt (kN)								
Grade 300	21.2	30.5	54.3	84.8	132.5	217.1	274.8	339.3
Grade 500	35.3	50.9	90.5	141.4	220.9	361.9	458.0	565.5

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