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## Introduction

CSP Pacific is New Zealand's only manufacturer of **Aluminium Multiplate** structures.

These structures have been used in New Zealand and around the world for many years and are a proven option for many civil infrastructure applications.

Design, manufacture and Installation requirements for **Aluminium Multiplate** structures are specified in **AS/NZS 2041: Buried Corrugated Metal structures**. This is a joint Australian and New Zealand Standard, and comprises of several parts. Those applicable to **Aluminium Multiplate** are as follows:

- AS/NZS 2041.1:2011 Buried Corrugated Metal Structures - Part 1 Design Methods
- AS/NZS 2041.2:2011 Buried Corrugated Metal Structures - Part 2 Installation Methods
- AS/NZS 2041.6:2010 Buried Corrugated Metal Structures - Part 6 Bolted Plate Structures

For a successful Multiplate installation, the three key stages of the process should be covered by the following parties:

Design	<b>Project engineer</b> CSP Pacific can provide a design guide if required.
Manufacture	<b>CSP Pacific</b>
Installation	<b>Qualified contractor</b> CSP Pacific can provide advice if required. CSP Pacific will provide all plate layout drawings and assembly instructions. Backfilling instructions should be stated by the project engineer.

This document is designed to complement the standard; not supersede it.

**Aluminium Multiplates** are manufactured from a marine grade aluminium alloy, 5052-H34, which offers **exceptional resistance to corrosion** in both fresh and marine water environments. This is due to the very protective tenacious aluminium oxide present on the surface of aluminium, which is almost inert in most natural environments. When mechanically damaged the oxide coating reforms immediately.

Corrosion of aluminium can occur due to inherent minor imperfections in the protective oxide film. This results in localised pitting attack, which is generally quite sparse, and slows down with time due to a build-up of corrosion products in the pit (pit depth has been found to be approximately proportional to the inverse of time cubed).

## Standards and Approvals

As mentioned above, before designing or installing an **Aluminium Multiplate**, CSP Pacific recommends obtaining a copy of the relevant parts of the **AS/NZS 2041 standard**.

All CSP Pacific **Aluminium Multiplate** structures are manufactured to this standard.

In addition to this standard, other relevant documents are:

- AASHTO. M-167-72 American Association of State Highway and Transport Officials Standards Specification for Structural Plate for Pipe, Pipe Arches and Arches.
- AREA 1-4-25 to 1-4-31 American Railway Engineering Association Manual for Highway Engineering Specification for Corrugated Structural Plate for Pipes, Pipe Arches and Arches 1972

## Technical Information

### Plate Details

The structural plates are fabricated from a structural grade aluminium alloy, 5052-H34, and have a corrugation of 200mm pitch by 55mm depth running at right angles to the length of the sections.

These sections are either 3mm to 5mm thick and are supplied in 2 net widths of 1175mm and 1410mm and two length options of 2.0 and 3.0 metres.

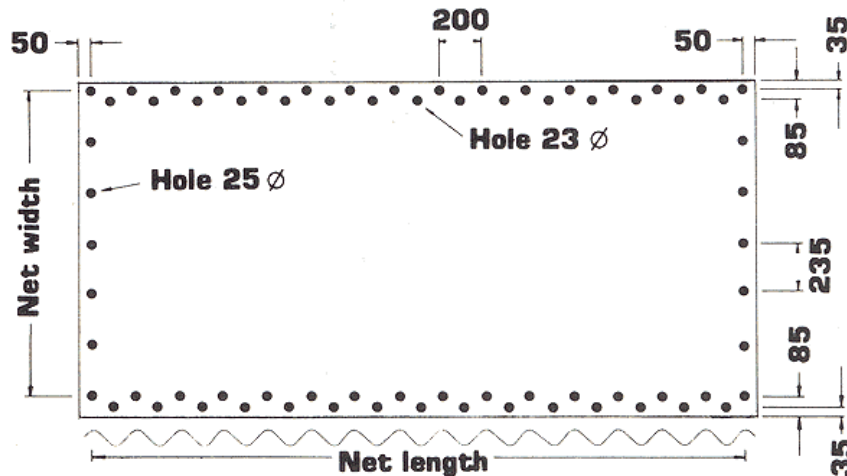
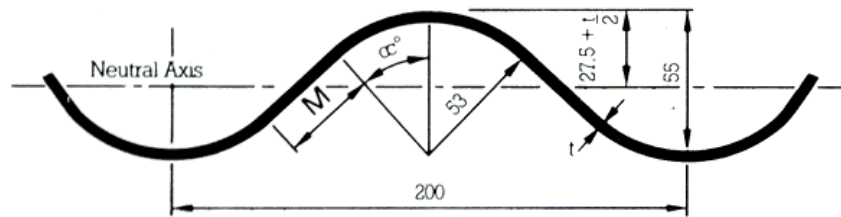


Plate Designation	52	53	62	63
Net Width (mm)	1175	1175	1410	1410
Overall Width (mm)	1300	1300	1530	1530
Net Length (m)	2.0	3.0	2.0	3.0
Number of Modules at 235mm centres	5	5	6	6
Number of Circumferential bolt holes	6	6	7	7

Plate Designation	Length (mm)	Approx Weight in Kg of Individual Plates without Bolts Material Thickness (mm)		Number of Bolts per Plate
		3.0mm thick	5.0mm thick	
52	2000	27	44	25
53	3000	40	65	35
62	2000	32	52	26
63	3000	47	77	36

### Physical Properties



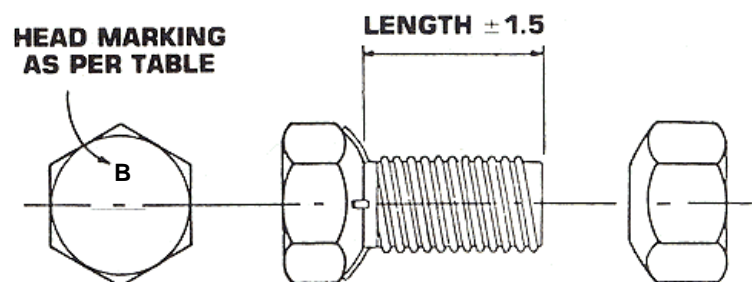
t (mm)	M (mm)	a (Degrees)	Moment of inertia (mm <sup>4</sup> /mm)	Section Modulus (mm <sup>3</sup> /mm)	Radius of gyration (mm)	Section area (mm <sup>2</sup> /mm)
3.0	32.2	45.2	1360	47	19.6	3.5
5.0	28.4	46.3	2290	76	19.7	5.9

## Bolts and Nuts

The individual plates are assembled with M20 high stress aluminium bolts with the underside of the head being shaped to fit tightly against the plate. Likewise the nut is similarly shaped. Bolts are supplied as follows and can be identified by the letter stamped on the head (A or B).

	Bolt Type	
	2 Plate Lap	3 Plate Lap
3mm	A	A
5mm	A	B
Assembly Bolts*	D	D
Arch Channels	A and C	

\* If Assembly bolts are required they are supplied in galvanised steel. These bolts should not be left in the structure once assembly complete.

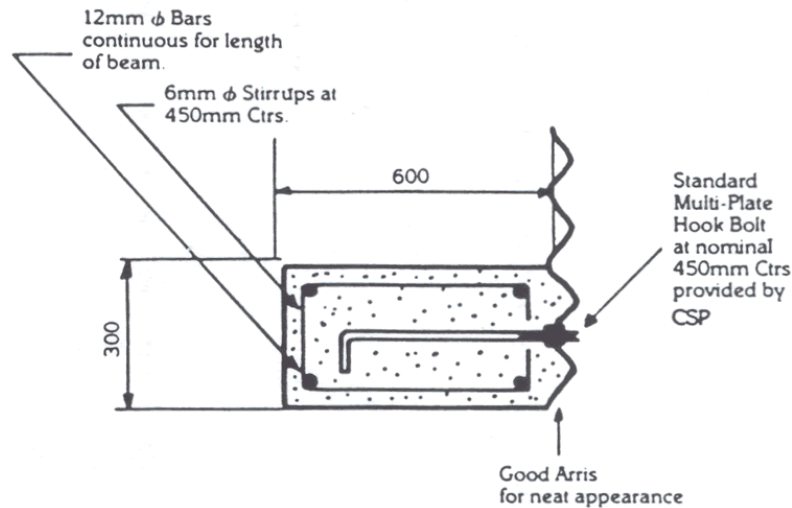


Head Marking	A	B	C
Length	38mm	50mm	90mm

\*\* No head marking

## Ring Beam Detail

Ring Beams are used to stiffen the ends of the structure. Their use is optional depending on the skew of the structure and the end treatment used. To determine when to use a ring beam see section 8 of AS/NZS 2041.1:2011 Buried Corrugated Metal Structures - Part 1 Design Methods.



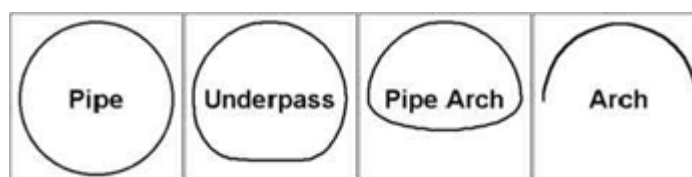
It is important to note that aluminium and steel will react if touching. Ensure the steel reinforcing for the ring beam does not touch the aluminium plates or the hook bolts by using plastic spacers or similar.

## End Treatments

**Aluminium Multiplate** can be manufactured with a variety of end treatments to suit site conditions. Standard end finishes are square ends, step bevels, skew bevels, full bevels and skew bevels. Where the skew angle exceeds 20° end plates should be reinforced with a concrete ring beam. Again, more detail can be found in AS/NZS 2041.1:2011 Buried Corrugated Metal Structures - Part 1 Design Methods.



## Available Profiles



The range of structures in this document complies with the flexibility requirements of the above shapes.

## Pipes



Nominal Diameter (m)	Periphery (m)	End Area (m <sup>2</sup> )	Plates per Ring		
			53	63	Total
1.80*	5.6	2.5		4	4
1.95	6.1	3.0	4	1	5
2.10	6.6	3.4	2	3	5
2.25	7.1	4.0		5	5
2.40	7.5	4.5	4	2	6
2.54	8.0	5.1	2	4	6
2.70	8.5	5.7		6	6
2.84	8.9	6.3	4	3	7
3.00	9.4	7.0	2	5	7
3.15	9.9	7.8		7	7
3.30	10.3	8.5	4	4	8
3.44	10.8	9.3	2	6	8
3.60	11.3	10.1		8	8
3.90	12.2	11.9	2	7	9
4.05	12.7	12.8		9	9
4.20	13.2	13.8	4	6	10
4.34	13.6	14.8	2	8	10
4.50	14.1	15.8		10	10
4.64	14.6	16.9	10	2	12
4.80	15.0	18.0	2	9	11
4.95	15.5	19.1		11	11
5.10	16.0	20.3	4	8	12
5.24	16.5	21.5	8	5	13
5.40	16.9	22.8		12	12

\* Denoted structure is difficult to manufacture. Please contact CSP Pacific for further information.

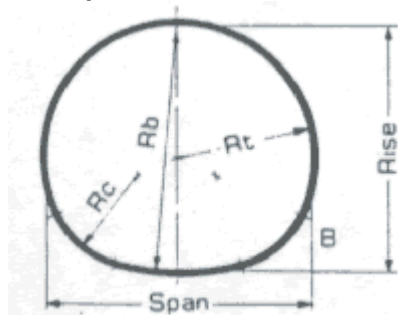
## Pipe Arches



Span (m)	Rise (m)	Periphery (m)	Area (m <sup>2</sup> )	B (m)	R <sub>c</sub> (m)	R <sub>t</sub> (m)	R <sub>b</sub> (m)	Plates per Ring	Corner Type S = Single Curved T = Dual Top/Cnr B = Dual Cnr/Btm
2.72	2.14	7.76	4.70	0.84	0.80	1.37	4.00	6	S
3.04	2.30	8.46	5.68	0.90	0.80	1.53	3.50	6	B
3.28	2.38	8.93	6.38	0.97	0.80	1.68	3.00	7	S
3.35	2.36	9.17	6.50	0.95	0.80	1.72	3.00	7	T
3.36	2.44	9.40	6.36	0.96	0.80	1.70	3.50	7	S
3.69	2.63	10.10	7.58	0.95	0.80	1.84	4.50	8	S
3.97	2.69	10.58	7.82	1.04	0.80	2.05	4.00	8	B
3.93	2.74	10.81	8.50	0.97	0.80	1.98	5.00	8	S
4.21	2.80	11.04	9.22	1.13	0.80	2.22	3.50	9	S
4.30	2.99	11.52	9.86	1.04	0.80	2.19	5.00	9	B
4.42	2.99	12.22	10.66	0.98	0.80	2.23	6.18	10	S
4.58	3.05	12.22	10.93	1.04	0.80	2.32	5.69	10	S
4.77	3.20	12.93	12.18	0.97	0.80	2.40	8.61	10	S
4.89	3.30	13.40	13.06	0.91	0.80	2.45	12.64	11	S
4.98	3.30	13.40	13.02	0.99	0.80	2.50	8.54	11	S
5.11	3.34	13.63	13.44	1.05	0.80	2.59	7.47	11	S
5.34	3.40	14.10	14.35	1.04	0.80	2.70	7.53	11	S
5.48	3.47	14.34	14.77	1.13	0.80	2.79	6.85	11	B
5.62	3.51	14.57	15.23	1.18	0.80	2.88	6.35	12	S
5.74	3.61	15.04	16.16	1.12	0.80	2.92	7.69	12	S
5.93	3.77	15.75	15.57	1.04	0.80	2.98	10.95	13	S
6.27	3.90	16.45	19.15	1.11	0.80	3.17	9.61	13	S
6.35	3.95	16.92	21.06	1.09	0.80	3.21	10.99	13	S

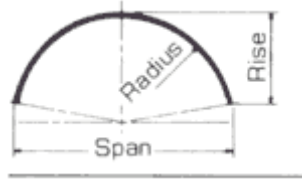
**Note:** For structures larger than 6.35m span, refer to CSP Pacific for special design.

## Underpasses



Span (m)	Rise (m)	Periphery (m)	Area (m <sup>2</sup> )	R <sub>c</sub> (m)	R <sub>t</sub> (m)	R <sub>b</sub> (m)	Plates/Ring
2.88	2.73	8.93	6.05	1.08	1.44	3.17	7
3.37	3.10	10.34	8.13	1.08	1.69	3.31	8
3.61	3.28	11.04	9.27	1.08	1.81	3.70	9
3.91	3.54	11.98	10.93	1.08	1.96	5.66	10
4.34	3.84	13.16	13.16	1.08	2.17	4.55	11
4.58	4.02	13.86	14.61	1.08	2.29	5.22	11
5.09	4.80	15.74	19.17	1.88	2.54	4.92	12
5.50	5.11	16.92	22.13	1.88	2.75	4.91	13
5.97	5.48	18.33	25.96	1.88	2.99	6.30	14
6.47	5.85	19.74	30.07	1.88	3.24	6.45	15

## Arches

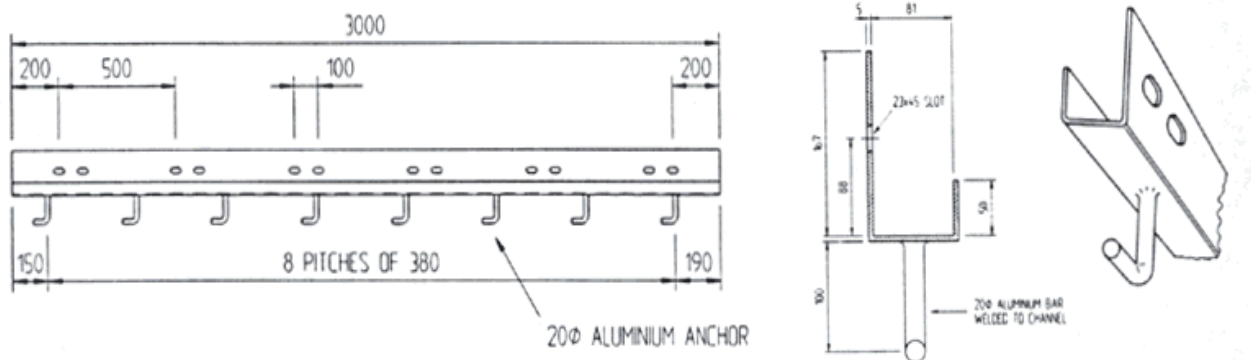


Span (m)	Rise (m)	Periphery (m)	Area (m <sup>2</sup> )	Radius (m)	Plates/Ring
2.00	0.89	2.94	1.30	1.01	2
2.50	1.10	3.64	2.01	1.26	3
3.00	1.31	4.35	2.88	1.51	3
3.00	1.49	4.82	3.53	1.50	4
3.25	1.48	4.82	3.56	1.63	4
3.50	1.39	4.82	3.49	1.80	4
3.50	1.64	5.29	4.31	1.75	4
3.75	1.56	5.29	4.25	1.91	4
3.75	1.61	5.76	5.13	1.88	4
4.00	1.59	5.52	4.61	2.05	4
4.00	1.85	5.99	5.55	2.00	5
4.00	1.97	6.23	6.02	2.00	5
4.50	1.80	6.23	5.88	2.30	5
4.50	1.93	6.46	6.42	2.27	5
4.50	2.06	6.70	6.95	2.26	5
4.50	2.18	6.94	7.48	2.25	5
5.00	2.01	6.94	7.32	2.56	5
5.00	2.14	7.17	7.91	2.53	6
5.00	2.39	7.64	9.09	2.50	6
5.00	2.51	7.88	9.68	2.50	6
5.50	2.22	7.64	8.91	2.81	6
5.50	2.35	7.87	9.56	2.78	6
5.50	2.60	8.34	10.86	2.75	6
5.50	2.72	8.58	11.50	2.75	6
6.00	2.43	8.34	10.66	3.07	6
6.00	2.56	8.58	11.37	3.04	6
6.00	2.81	9.05	12.78	3.01	7
6.00	2.93	9.28	13.48	3.00	7
6.50	2.50	8.81	11.07	3.36	7
6.50	2.63	9.05	12.56	3.32	7
6.50	2.89	9.52	14.10	3.27	7
6.50	3.14	9.99	15.63	3.25	7

**Note:** For structures larger than 6.5m span, refer to CSP Pacific for special design.

## Base Channel detail for Arches

dimensions in mm





## General Assembly Instructions

These instructions enable corrugated **Aluminium Multiplate** structures to be simply and accurately built. **However it is essential that the General Assembly Drawing supplied for the particular structure be carefully read before starting.** This drawing provides the specific details of the structure, which are not included in these general instructions.

### Assembly Times

The following simple formula will give approximate times for the assembly of **Aluminium Multiplate** structures based on results of many Multiplate assemblies. The formula is a guide only as assembly times can vary due to site conditions and contractor experience.

Mathematically  $T = L \times P \times F$

$T =$  Assembly time in man hours

$L =$  Invert length in metres

$F =$  0.70 For Pipes  
0.85 For Pipe-Arch & Underpass  
1.00 For Arches

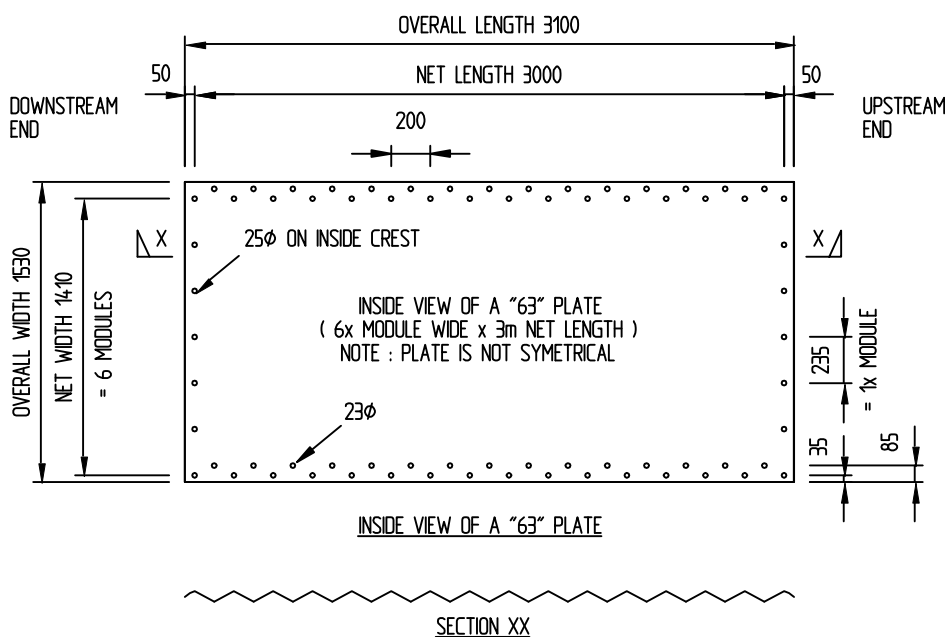
$P =$  Number of plate per ring

$F =$  Factor of difficulty and varies with the type of structure, size, accessibility of site assembly crew experience and use of mechanical handling equipment. Some interpolation is necessary in determining  $F$  depending on crew skill and site conditions.

### Plate Geometry

The individual plates for **Aluminium Multiplate** structures come in two widths and two lengths:

Plate Designation	52	53	62	63
Net Width (mm)	1175	1175	1410	1410
Overall Width (mm)	1300	1300	1530	1530
Net Length (m)	2.0	3.0	2.0	3.0
Number of Modules at 235mm centres	5	5	6	6
Number of Circumferential bolt holes	6	6	7	7



## Sorting of Plates

Each plate is identified by a 10 digit code stamped in the centre of the ends of plates. The first four digits indicate the radius (mm) that the plate has been curved to. The next five digits are the last five digits of the CSP Pacific job number and a single number indicating the plate thickness in mm follows this.

Plates are sequentially numbered on the assembly drawing to show the recommended order of plate assembly. This numbering does not physically appear on the plates themselves.

Pipe arch and underpass structures require plates to be curved to various radii. In this case plates will be colour coded so that the different curvatures can be easily recognised.

Usually one plate in the assembly will have been weld marked with the structure's identification code. Refer to the assembly drawing to see where this plate is to be placed.

## Skew and Bevel Plates

If the structure is to be erected with skewed or bevelled ends, look for embossed identification marks on the inside of each cut plate, and place these cut plates in accordance with the assembly drawing supplied with this order.

## Bolts and Nuts

All bolts and nuts used in the permanent construction of **Aluminium Multiplate** structures shall be aluminium themselves. No dissimilar materials to be left permanently attached to the aluminium structure.

Bolt and nut threads must be kept free from dirt and other such debris as dirty threads will bind before correct bolt tightness is achieved or have their heads shear off before the plates have drawn together.

In the event of threads binding before correct assembly is achieved, grind off the head and discard. Do not attempt to re-use these bolts and nuts.

3mm structures are supplied with "Type A" bolts (38mm long) for assembly.

5mm structures are supplied with "Type A" bolts (38mm long) for two plate laps and "Type B" bolts (50mm long) for 3 plate laps. Refer to assembly drawing for details.

Eight (8) special "No. 5" galvanized steel service bolts (75mm long) are provided to temporarily draw plates together where needed. These bolts and nuts shall not be left permanently attached to the structure.

The curved surface of a nut is to be placed in contact with the surface of a plate. The placement of nuts can be either on the inside or the outside of the structure and is at the discretion of the installer.

Bolting plates at the circumferential seam is best done by first placing two bolts near the middle of the plate. Initially bolts should be left loose to make aligning of bolt holes easier. Connect each plate to its adjacent plates using three or four loosely tightened bolts in longitudinal seams near centres of plates. Insert corner bolts. After assembling the desired number of plates, insert the balance of the longitudinal bolts working from the centre toward corners of plates. Keep bolts loose. Final tightening of the bolts locks the plates and should proceed a few rings behind, bolting from the centre of each plate outwards to corners.

## Propping

Internal / external props are often required during the assemble process. They are used to hold unsupported plate in position at the assembly interface, or to achieve correct cross sectional profile prior to and during bolt tightening / torquing.

Short props are essential for the assembly of arches, as the side/ bottom plates are free to rotate in the channel footings (channel bolts are not to be used to support these plates). Acro props with push/pull facility and fitted with swivel plates are particularly useful.

## Assembly

### Assembly of Pipes and Pipe Arches

Before starting to assemble the structure, study the site specific General Arrangement Drawing supplied by CSP Pacific paying particular attention to the Details 'A' and 'B' showing the orientation of the plates and the stagger of the joints as these are vitally important. **Plates are not symmetrical and must be oriented correctly.**

The laying sequence shown on the **Plate Layout Detail** on the drawing is suggested to minimise the possibility of misalignment of the structures.

The first stage of assembly consists of laying the specified number of bottom plates and checking the alignment before tightening the bolts fully. Once these plates have been correctly laid, aligned and tightened they provide a rigid spine or 'keel' and effectively fix the alignment of plates subsequently added.

The second stage of assembly is to add the next specified number of plates in sequence to build up the 'ring'. Plates should be added to each side of the bottom plates alternatively to maintain equilibrium until the top plate can be added to complete the first whole 'ring' of the structure. By adding plates in this way, any tendency for the structure to 'rifle' or wander out of alignment is minimised.

For short structures the full length of bottom plates are laid in the first stage and stage two effectively completes the structure if the assembly sequence is followed through.

In the case of longer structures, the methodology of the first two stages shall be repeated for subsequent segments of the structure to ensure that slope and alignment are maintained.

If, due to site conditions (e.g., limited access to a crane or lifting gear), the assembly sequence cannot be followed it may be necessary to temporarily prop the 'out-of-balance' side. Additionally it may be found necessary to insert plates between previously laid plates in order to maintain the specified 3 plate laps and stagger.

While initially assembling the structure, connect side and top plates with as few bolts as possible. Insert sufficient bolts (every second crest is suggested) in each seam to hold the plates in position, but do not tighten the nuts, thus leaving the plates free to move slightly to facilitate matching the remaining bolt holes. About three rings behind the plate assembly, insert remaining bolts using drift pins and pointed pry bar to align the holes. After all bolts are in place tighten nuts.

### Assembly of Arches

For arches, starting at the outlet end, assemble three or four plates on one side only. Bolt these plates to the base channel with bolts at alternating 400mm and 600mm intervals. The bolts are for location only; they are not load bearing. The unsupported edge of these plates must be held up with suitable temporary props.

After placing a few plates on one side, start again at the outlet end and assemble plates on the opposite side. When the arch is connected to the base channel, the plates on one side of the arch should have the lowest row of bolt holes in the outside crests of the corrugation.

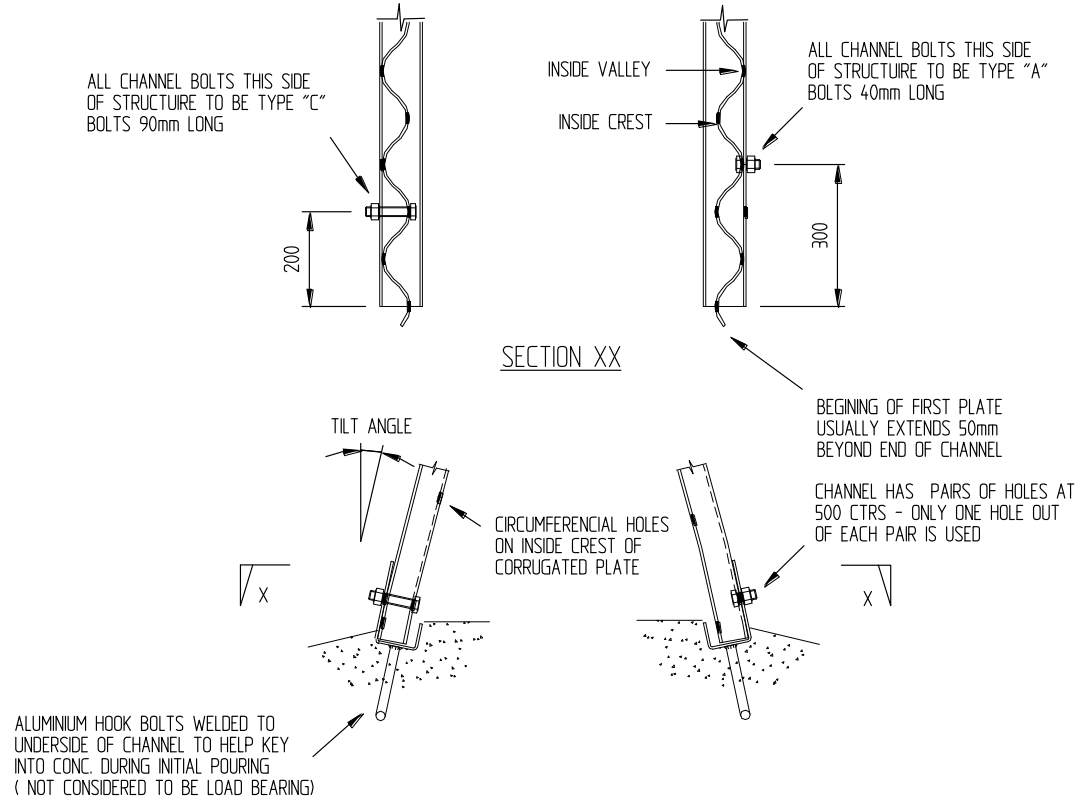


Figure 2 - Section through arch footing at downstream end.

Plates on the opposite side should have lowest row of bolt holes on the outside valleys of the corrugations, otherwise the plates will not match when they meet at the crown of the arch. Note that long bolts, i.e. 90mm length, are used on outside valleys and short bolts are used on outside crests. Refer to figure 2.

Additional plates are placed on both sides until the first "ring" is complete. Add only sufficient side plates to close the top of the arch, always working from the outlet end, lapping each plate one corrugation and using only sufficient bolts in each seam to hold the plates in position but do not tighten nuts.

After the arch is closed on top, the remaining side and top plates are added closing the top progressively towards the inlet end. After all plates are in place, insert remaining bolts using drift pins and pry bars to align the holes. After all bolts are in place, tighten nuts. Recommended range for bolt torque - see previous section.

Adequate temporary bracing or props should be used throughout the assembly process to ensure correct structure shape is achieved. Short props are essential for the assembly of arches, as the side/ bottom plates are free to rotate in the channel footings (channel bolts are not to be used to support these plates). Acro props with push/pull facility and fitted with swivel plates are particularly useful.

## Bolt Torque

All bolts shall be tightened along all longitudinal and circumferential seams prior to backfill placement.

Bolts shall be tightened to a torque value of **170 Nm (125 lb.ft) ± 35 Nm (26 lb.ft)**. Maintain a balanced progression of tightening with respect to axis of the structure to prevent 'rifling' tendency. Final tightening should be carried out in a similar sequential order to the plate assembly.

To ensure the specified bolt torque is achieved, 1 percent of bolts in the longitudinal seams shall be tested. The installation shall then be considered acceptable if the specified torque requirements are achieved in at least 90 percent of the bolts tested. Otherwise the design needs to be checked to determine whether the bolt torque values achieved are acceptable.

- Bolt torque values at the lower end of the range given are preferable to higher values so that the corrugations of lapping plates are closely nested and aligned and not damaged by excessive bolt tightening.
- Information on inspection of bolt tightness is provided in NZS 3404 1&2: 1997 Steel Structures Standard

## Assembled Structure Tolerances

**Structure Length** – The actual length shall differ from the length specified on the assembly drawing by no more than 1 percent. Structure length variations arise due to both manufacturing tolerances and erection procedures. In most cases, the assembled structure is longer than the desired length.

**Structure Cross-sectional Shape** – The actual internal span and rise dimensions of the assembled structure after bolt torquing and prior to backfilling shall not differ from the shape shown on the assembly drawing by more than ± 2 percent.

For arches with a span greater than 6000mm, the final shape shall not differ from the specified shape by more than ± 2 percent.

Cross sectional measurements of the assembled structure at the inlet and outlet ends as well as two intermediate positions shall be recorded as part of the QA process.

## Foundation Preparation and Backfilling

### General

The contractor responsible for assembly and / or installation of **Aluminium Multiplate** structures shall carry out all works in accordance with the minimum requirements in the following two documents unless specified by Project Engineer:

1. Transit New Zealand Specification F/1 and F/1 Notes – Earthworks Construction  
The design standard AS/NZS 2041.2:2011 Buried Corrugated Metal Structures - Part 2 Installation Methods. Topics covered in this standard relate specifically to Multiplate structures and include:
  - Foundation preparation
  - Backfill selection and placement
  - Minimum cover for abnormal loads
  - Structure Shape

The following instructions supplement the information provided in AS/NZS 2041.2:2011 Buried Corrugated Metal Structures - Part 2 Installation Methods but do not replace adequately detailed specifications appropriate to the project to be supplied by the project engineer.

### Foundation Preparation

Where a firm foundation is not encountered, soft or unstable soil under each structure for a width of not less than twice the span of the structure shall be removed and replaced with suitable material thoroughly compacted to provide adequate support for the installation. Otherwise special construction methods shall be adopted.

Note that unstable foundation material will not provide even support and can shift after the embankment is constructed causing cross-sectional and/or longitudinal distortion of the structure.

Where rock is encountered in the foundation, the rock should be removed below the bedding over the width which will ensure that the structure will not bear on rock. The rock shall be replaced with a bed of compacted granular material with thickness not less than structure span/4, or 250mm, whichever is the lesser.

In unstable soils, the use of cut-off walls at the ends of hydraulic structures is recommended. Foundation preparation is critical, if in doubt check with the project engineer or consult CSP Pacific.

## Bedding

Bedding under all structures or a firm foundation shaped to the structure profile shall be provided. For installation in trenches the width of the trench up to the level of the top of the pipe or pipe-arch shall be the least practicable but adequate to permit the compaction of the backfill material under the haunches and at the sides of the pipes or pipe-arches.

Bedding shaping shall be sufficient to permit adequate compaction of the backfill under the haunches of the structure. Bedding may be relieved at bolting rings to permit bolts to be inserted from the underside of plates. A uniform blanket of loose granular material of 12mm maximum aggregate size should cover the shaping bedding to a depth sufficient to allow the corrugations to become filled with the material.

Note that bedding shaping to fit the entire base of the structure can interfere with assembly of field-bolted structures and is often costly as well as being unnecessary.

Precautions must always be taken to prevent scouring of the bedding material.

## Camber

Where the structure is installed under a high embankment and settlement of the foundation is anticipated, provision of a longitudinal camber should be considered. The amount of camber will depend on the height of the embankment and on the supporting strength of the soil in the foundation. Cambered bedding must always present an even grade for assembly. Calculations of camber should always be carried out by suitably qualified and experienced engineers.

## Material Selection

Backfill material should preferably be granular to provide good structural performance. Cohesive type material may also be used if careful attention is given to compaction at optimum moisture content. Very fine granular material shall be avoided when a high ground-water table is anticipated as it may infiltrate into the structure. In general avoid:

- highly plastic clays and silts
- organic clays and silts
- soils with rocks and hard lumps which will not pass a 75mm sieve

If abnormal conditions exist at a specific site or if unusual performance is expected of a structure and embankment, a soils engineer should be consulted for design and specification of the backfill.

## Placing Backfill around Structure

Unless otherwise specified by the designer, compaction values for select fill shall be measured by one of the following parameters, as applicable:

**Cohesive Soils** – each layer of select fill shall be compacted to not less than 90 percent of the dry density ratio for standard compaction. The dry density value (RD) shall be determined in

accordance with as 1289.5.4.1, based on the field dry density in accordance with AS 1289.5.3.2, AS 1289.5.8.1 and the maximum dry density in accordance with AS 1289.5.1.1/NZS 4402.4.1.1.

**Cohesionless Soils** - each layer of select fill shall be compacted to not less than 70 percent of the maximum density index for standard compaction. The density index (ID) shall be determined in accordance with as 1289.5.6.1, based on the maximum and minimum dry densities in accordance with AS 1289.5.5.1/NZS 4402.4.2.1 and NZS 4402.4.2.2 and the field dry density in accordance with AS 1289.5.3.1/NZS 4402.5.1.1, AS 1289.5.3.2, AS 1289.5.3.5/NZS 4402.5.1.5 or AS 1289.5.8.1.

Fill materials around the under the haunches of the structure shall be placed simultaneously on both sides in layers not more than 150mm thick when compacted. The backfill material shall be placed evenly to keep it at the same elevation on both sides of the structure at all times.

The backfill material should extend one diameter each side of the culvert. Where a trench has been excavated this condition does not apply. The minimum distance in this case is 300mm.

Pipe-arches require that the backfill at the haunches be of the selected material and be especially well tamped. Tamping may be done with hand or mechanical equipment, tamping rollers or vibrating compactor, depending upon field conditions. Note that it is essential that tamping be done carefully to ensure a thoroughly compacted backfill. Compaction of fills by puddling or jetting produce unsatisfactory backfills and should not be used.

## Compaction Equipment

### *Hand Equipment*

For tamping under the haunches of structures, hand tampers are generally needed to work in the small areas. Hand tampers from compacting horizontal layers should preferably weigh not less than 9kg and have a tamping face not larger than 150 x 150mm.

### *Mechanical Tampers*

Most types of power tampers are satisfactory and can be used in all except the most confined areas. However, they must be used carefully and completely over the entire area at each layer to obtain the desired compaction. Striking the structure with tamping tools must be avoided.

### *Tamping Rollers*

Where space permits, sheepsfoot, rubber-tyred and other types of tamping rollers can be used to compact backfill around the structure. If rollers are used, backfill adjacent to the structure shall be tamped with hand or hand-held power equipment.

Particular attention should be given to keeping the backfill at the same elevation on both sides of the pipe.

### *Vibrating Compactors*

Vibrating equipment can be used to compact granular backfills.

## Fill Over Structure

Filling over the corrugated plate structure shall be completed with materials essentially the same as those used for the surrounding backfill, placed and compacted in the same manner.

## Protection of Structure From Overload

When heavy construction equipment is required to travel over the structure it is essential that the structure be checked for loading condition.

When an overload condition occurs the amount of temporary additional cover required to permit passage of the equipment over the structure is to be calculated in accordance with AS/NZS 2041.1:2011 Buried Corrugated Metal Structures - Part 1 Design Methods.

## Temporary Bracing

During backfill and the construction of head walls, the ends of structures may require temporary ties to prevent distortion.

## Backfilling of Arches

Arches require special care when placing backfill, especially half-circle or horseshoe type arches. This is because arches have a tendency to shift sideways or to peak up under backfilling loads. For example if one side is backfilled more than the other, the arch will move away from the larger load. If both sides are backfilled equally and tamped thoroughly the top of the arch may peak unless fill has been placed on it (or the crown otherwise temporarily anchored). Ideally backfilling should be placed in layers conforming to the shape of the arch.

Peaking of half-circle arches can be a problem and must be watched carefully. One technique is to build a ramp near the centre of the arch to allow placement of substantial fill over the crown. Backfilling then proceeds outwards towards the ends. It is good practice to monitor peaking by monitoring plumb bobs fixed to the arch crown.

## Backfilling Arches with Headwalls

Backfilling of arches with substantial headwalls should proceed from one end, making sure that sufficient fill is placed over the crown.



## Maintenance Inspections of Multiplate Structures

All Multiplate Structures should be inspected on a routine basis to assess their condition and ensure they are functioning properly. Inspections should be carried out annually and always after a major weather event such as flooding and storms.

An on-going maintenance system should be implemented as follows:

- A yearly visual inspection of the structure.
- The inverts of all structures kept clear of any large debris such as trees and boulders.
- Structures with a waterway area of greater than 3.5m<sup>2</sup> should be inspected in accordance with Transit New Zealand Bridge Inspection Policy TNZ S6:2000.
- Where the structure is located close to the sea and /or have high traffic volumes through the structure, a high pressure water wash should occur every 5 years.
- Any ground water drains flushed occasionally to make sure there are no blockages.
- In the case of enclosed structures such as pipes and pipe arches, the invert inspected for signs of deterioration.
- In the case of Pedestrian and Motor Vehicle Underpasses the area at the interface of the multiplate and the footings should be regularly cleared of debris to avoid accelerated degradation of the walls of the structure.
- After heavy rain or flooding events inspect the backfill to make sure there is no scouring on the outside of the structure. This is especially important at the inlet end as this could result in water forcing its way along the outside of the structure. This action can create voids in the backfill and possibly affect the structural integrity of the installation.

Advice on repair of damaged Multiplate Structures is available on application from CSP Pacific.