

STR-02 FOOTING DESIGN

36 REINFORCED CONCRETE PAD FOOTINGS — 45-PANEL LOW GROUND MOUNT

Detailed elaboration of Attachment E to the Solar Cell System Installation Service Contract

Project	45 × LONGi 650 W off-grid PV array, low ground-mounted fixed structure (STR-02)	Document	TN-20261019-STR-FTG01 Rev01
Site	Chiang Rai, Thailand	Date	19 October 2026
Employer	Private client (name withheld)	Status	Issued for construction
Designed and built by	Solar ESS Co. Ltd. (single responsible contractor for the system, structure and footings, Clause 2)		

Purpose. This note turns Attachment E into a working design for the site team. It gives the set-out coordinates of all 36 footings, dimensioned footing and reinforcement details, the design check behind the contract figures (uplift 446 kgf, safety factor 1.58), the material quantities, the construction sequence and the inspection hold points. The footing size, depth, concrete grade, reinforcement and anchors are those of the signed contract and its Attachment A; nothing here changes the Contract Price or scope. Items marked “**recommended**” are good-practice details added for construction and are carried at Solar ESS’s cost.

1. Design summary

Item	Design
Number and type	36 identical isolated pad footings with stem, one under each steel post (3 rows × 2 purlin lines × 6 posts)
Pad	0.80 × 0.80 m, 0.15 m thick; underside 0.60 m below finished ground; on a 50 mm compacted gravel seat
Stem	0.25 × 0.25 m, from top of pad (−0.45 m) to finished ground level (±0.00)
Concrete	240 ksc (cylinder), max. aggregate 20 mm, slump 75–100 mm; 0.124 m³ per footing, 4.47 m³ net in total
Reinforcement	DB10 SD40: bottom mesh 5 bars each way at 150 mm; 4 vertical bars in the stem with 150 mm hooks into the pad. Stem ties RB6 at 150 mm (recommended)
Anchors	2 × M12 J-bolt, L = 300 mm, 250 mm embedment, 110 mm apart on the east–west (row) axis
Backfill	Excavated soil, free of roots and stones > 50 mm, compacted in 150 mm layers with a plate compactor
Design load	Wind uplift 446 kgf (interior post) / 223 kgf (row-end post), DPT 1311-50, Chiang Rai, V = 25 m/s
Result	Uplift safety factor 1.58 (interior) and 3.0 (row end); bearing 1.9 t/m²; anchor, stem and post stresses all well within limits (Section 5)

3. Row section and post heights

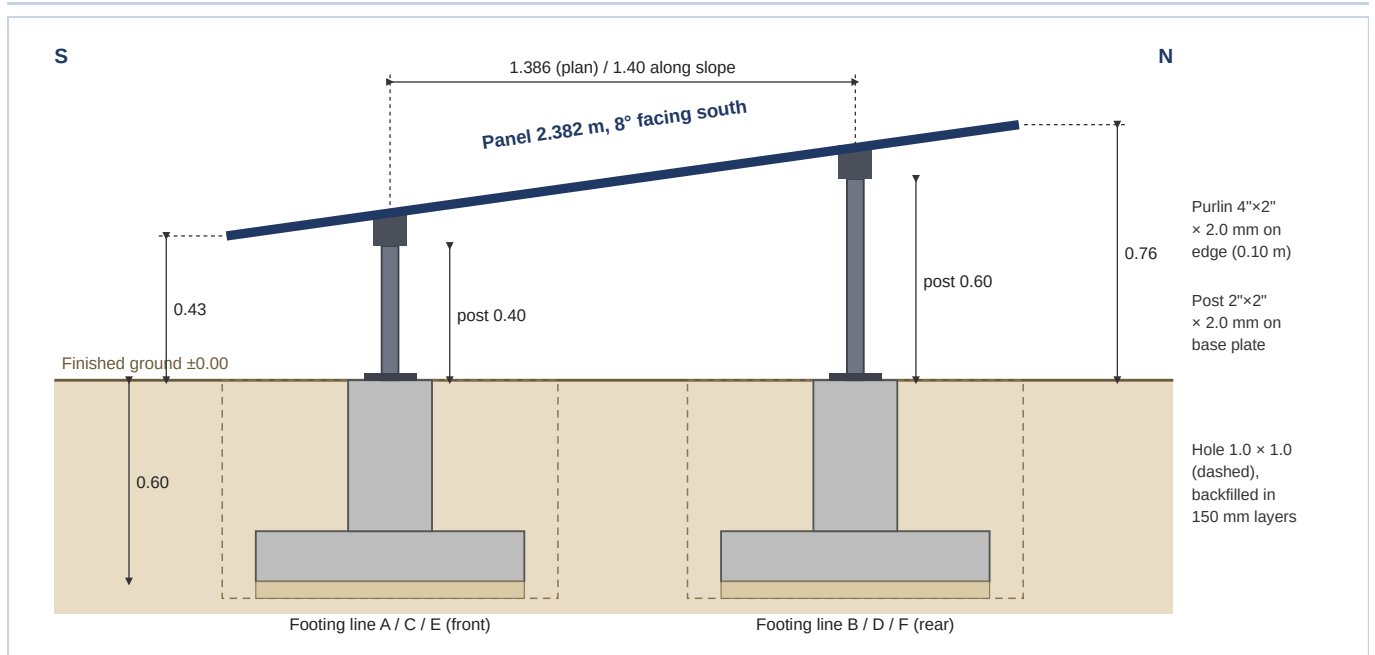


Figure 2 — Section through one row, looking west (scale approx. 1:20 on A4). Heights in metres above finished ground; panel heights are to the underside of the panel at its low and high edges.

Post	Footing lines	Quantity	Post length	Purlin underside	Panel underside at purlin
Front (south)	A, C, E	18	0.40 m	+0.40 m	+0.50 m
Rear (north)	B, D, F	18	0.60 m	+0.59 m	+0.69 m

Post lengths include the base plate and cap plate. All stem tops in one purlin line must be at the same level (± 5 mm) so the purlin sits straight; any difference in ground level is taken up in the stem height, never by packing under the base plate by more than 5 mm.

4. Footing details

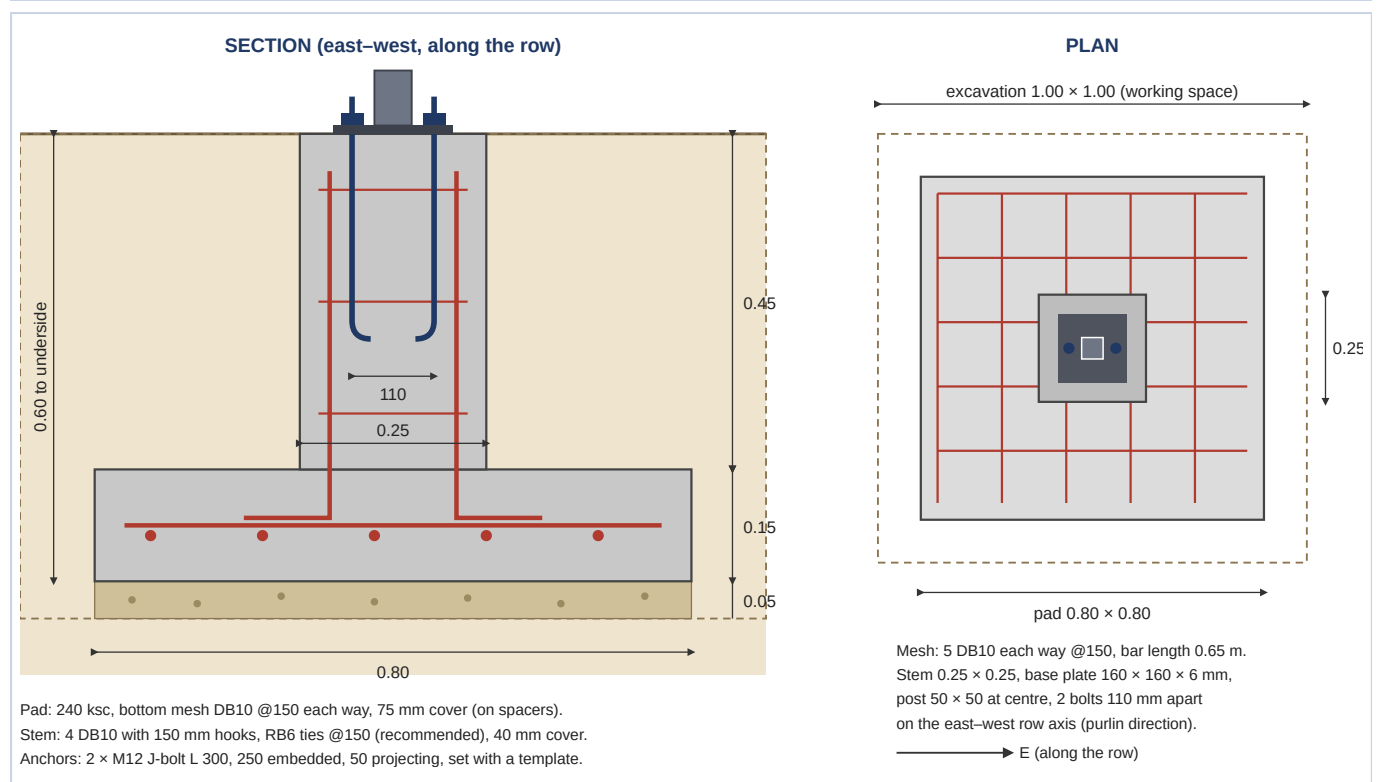


Figure 3 — Typical footing, section and plan (all 36 footings identical; dimensions in metres unless shown in mm).

4.1 Base plate and anchor detail

Part	Detail
Base plate	160 × 160 × 6 mm steel plate, 2 holes Ø14 mm at 110 mm centres (25 mm edge distance), from the plate allowance in Attachment A item 32
Post to plate	2"×2" × 2.0 mm tube centred on the plate, 4 mm fillet weld all round; grind and coat with zinc-rich primer + PU top coat as the rest of the structure
Anchor bolts	M12 J-bolt, L = 300 mm (250 mm in concrete, hook 40 mm), 50 mm projection; one washer and one nut each, plus a second (lock) nut recommended
Setting bolts	Cast in wet concrete through a plywood template with two Ø14 holes at 110 mm, aligned with the string line of the purlin; check 110 ±3 mm and plumb before the concrete sets
Levelling	Stem top trowelled level to the line level (±5 mm). Fine adjustment with steel shims ≤ 5 mm; larger errors are corrected by grinding or a 1:2 cement-sand bedding, never by stacking shims

5. Design check

5.1 Wind uplift (DPT 1311-50, Chiang Rai)

Step	Value
Reference wind speed V (50-year, Chiang Rai)	25 m/s
Reference velocity pressure $q = \frac{1}{2} \rho V^2$ ($\rho = 1.25 \text{ kg/m}^3$)	$390.6 \text{ N/m}^2 = 39.8 \text{ kgf/m}^2$
Exposure factor C_e (open terrain, height < 6 m) $\times$ gust factor $C_g \times$ importance I_w	$0.9 \times 2.0 \times 1.0 = 1.80$
Net uplift coefficient $C_{p,net}$ (free-standing mono-slope canopy, 8°)	0.82
Design net uplift pressure $p = q \times C_e \times C_g \times I_w \times C_{p,net}$	58.8 kgf/m²
Row area (17.30 m $\times$ 2.382 m panel length)	41.2 m ²
Total uplift on one row	2,422 kgf
Share taken by the windward purlin line	92% $\rightarrow$ 2,228 kgf over 5 spans
Interior post (tributary 3.46 m = 1/5 of the line)	446 kgf (contract value)
Row-end post (tributary 1.73 m = 1/10 of the line)	223 kgf

Wind from the north lifts the rear line (B, D, F) most; wind from the south lifts the front line (A, C, E). Because all 36 footings are identical, each one is designed for the worst case and either direction is covered.

5.2 Uplift resistance (dead load only, taken at 90%)

Weight resisting uplift	Interior post	Row-end post
Concrete: pad 0.096 m^3 + stem $0.028 \text{ m}^3 = 0.124 \text{ m}^3 \times 2,400 \text{ kg/m}^3$	298 kg	298 kg
Compacted soil directly above the pad: $(0.64 - 0.0625) \text{ m}^2 \times 0.45 \text{ m} \times 1,600 \text{ kg/m}^3$	416 kg	416 kg
Share of panels, purlins, post and plates	70 kg	37 kg
Total dead load	784 kg	751 kg
Resisting weight at 90%	706 kg	675 kg
Safety factor against uplift (required ≥ 1.5)	706 / 446 = 1.58	675 / 223 = 3.03

Conservative: only the vertical soil block over the pad is counted (no spreading cone and no side friction), so the soil weight of 416 kg depends on proper compaction in 150 mm layers (Section 7, hold point H5). A loose backfill must be re-dug and re-compacted.

5.3 Other checks

Check	Calculation	Result
Soil bearing (downward wind + dead load)	$(446 + 784) \text{ kg} / 0.64 \text{ m}^2 = 1.9 \text{ t/m}^2 \approx 19 \text{ kPa}$, against a presumed allowable 5 t/m^2 for firm natural soil at 0.6 m	OK (× 2.6)
Sliding / lateral load	Horizontal wind component $446 \times \sin 8^\circ \approx 62 \text{ kgf}$; passive soil resistance on the 0.8 m pad face at 0.6 m depth $\approx \frac{1}{2} \times 3.0 \times 1,600 \times 0.6^2 \times 0.8 = 691 \text{ kg}$	OK (× 11)
Anchor bolts in tension	$446 / 2 = 223 \text{ kgf}$ per bolt; M12 (stress area 0.843 cm^2) at $1,400 \text{ kg/cm}^2$ allowable = $1,180 \text{ kgf}$	OK (× 5.3)
Anchor pull-out	J-bolt 250 mm in 240 ksc concrete: bond $\approx 940 \text{ kgf}$ per bolt plus hook, against 223 kgf	OK (× 4)
Stem in tension	$4 \text{ DB10} = 3.14 \text{ cm}^2 \times 2,000 \text{ kg/cm}^2$ (SD40 allowable) = $6,280 \text{ kgf}$, against 446 kgf	OK
Pad bending	Soil load on the 0.275 m cantilever under uplift is small; DB10 @150 exceeds minimum steel for a 0.15 m slab	OK (minimum steel governs)
Post at base (rear post, 0.60 m)	$M = 62 \text{ kgf} \times 0.60 \text{ m} = 37 \text{ kgf}\cdot\text{m}$; $2'' \times 2'' \times 2.0 \text{ mm}$ tube, $S = 5.9 \text{ cm}^3 \rightarrow 630 \text{ kg/cm}^2$ against $1,440 \text{ kg/cm}^2$ allowable	OK (× 2.3)

5.4 If the footing must change on site (Clause 2)

Where rock, groundwater, a buried service or soft soil prevents the standard footing, Solar ESS may use another suitable type. Any alternative must give an uplift safety factor of at least 1.5 on 446 kgf with dead load at 90%, meaning at least **673 kg of footing weight** (concrete plus soil held on it) for an interior post. Examples:

- **Rock at less than 0.6 m:** stop at rock, cast the pad on cleaned rock and add two Ø12 dowels drilled 150 mm into the rock and grouted, or increase the pad to make up the lost soil weight.
- **Surface ballast block** (no digging): plain concrete $0.90 \times 0.90 \times 0.40 \text{ m} = 778 \text{ kg}$, on levelled and compacted ground, with the same anchor bolts.
- **Soft or wet bottom:** dig out to firm soil, replace with compacted gravel in 100 mm layers and keep the pad underside at 0.60 m below finished ground.

Each change is recorded with its footing ID, a photo and the reason, and reported in the progress update.

6. Material quantities

Material	Specification	Per footing	36 footings (net)	Attachment A allowance
Excavation	1.00 × 1.00 m to 0.65 m depth	0.65 m ³	23.4 m ³	in labour (item 46)
Gravel seat	50 mm compacted, under the pad only	0.032 m ³	1.15 m ³	1.3 m ³ (item 42)
Concrete	240 ksc; pad 0.096 + stem 0.028 m ³	0.124 m ³	4.47 m ³	4.9 m ³ (item 38)
Reinforcement	DB10 SD40: mesh 10 × 0.65 m + stem 4 × 0.70 m	9.3 m	335 m (34 bars)	36 bars × 10 m (item 39)
Stem ties (recommended)	RB6, 3 ties of 0.90 m per stem	2.7 m	97 m (10 bars)	added by Solar ESS
Anchor bolts	M12 J-bolt L 300 + nut + washer	2 sets	72 sets	72 sets (item 33)
Base plates	160 × 160 × 6 mm (1.2 kg)	1	36 (43 kg)	within 86 kg (item 32)
Formwork	Stem box 0.25 × 0.25 × 0.45 m, plywood, reused	—	6 boxes, reused	item 41
Backfill	Excavated soil, compacted in 150 mm layers	0.49 m ³	17.8 m ³	item 43 (compactor)
Surplus soil	Spread level on site or removed (Employer's choice)	≈ 0.16 m ³	≈ 5.6 m ³ + bulking	—

7. Construction sequence and hold points

- Site handover — H1.** The Employer confirms the array location in person and the area is filled and levelled by the Employer (Clause 2, Site). Record the finished ground level as ±0.00 with a benchmark peg outside the work area.
- Set-out — H2.** Fix line A from the datum, square off with a 3-4-5 triangle and peg lines A–F and columns 1–6 on profile boards 1.5 m outside the array. Check both diagonals (18.779 m) to ±20 mm before digging. Mark each pit 1.00 × 1.00 m.
- Excavation.** Dig to 0.65 m below ±0.00 with vertical sides. Remove loose soil and roots and keep the bottom flat and dry. If rock, water, a pipe or soft spots appear, stop and apply 5.4.
- Bottom check — H3.** Depth 0.65 m (+0 / –20 mm); the bottom is firm (a boot heel leaves only a shallow mark). Place and compact 50 mm of gravel under the pad area and check that the top of the gravel is at –0.60 m.
- Reinforcement — H4.** Lay the DB10 mesh on 75 mm concrete spacers, tie the four stem bars with hooks into the mesh, and fit RB6 ties at 150 mm. Check bar count, spacing and cover, and photograph each footing before pouring.
- Pour the pad.** Pour 240 ksc concrete to 0.15 m, rodded or vibrated and finished flat. Set the stem box on the fresh pad, plumb and on the line, then pour the stem the same day so pad and stem act as one.
- Set the anchor bolts.** Fix the template on the stem box on the purlin string line (110 mm bolt centres, 50 mm projection) and trowel the stem top level to the line level ±5 mm. Check plumb and spacing again before the concrete sets.
- Curing.** Strip the stem box after 24 h. Keep the concrete wet under sacks for at least 7 days, and do not load the bolts before 7 days.
- Backfill — H5.** After stripping, backfill around the stem in 150 mm layers (three layers to ground level), each compacted with the plate compactor at slightly moist condition, with no stones over 50 mm and no organic material. Grade the surface to fall away from the stem.
- As-built survey — H6.** Record the position, top level and bolt spacing of all 36 footings on the footing record sheet before erecting the posts.

7.1 Tolerances and records

Item	Tolerance
Footing centre position (X, Y)	±20 mm from Section 2.1
Purlin line straightness (bolts in one line)	±10 mm from the string line
Stem top level, footings in the same purlin line	±5 mm
Pad underside depth	-0.60 m, +0 / -20 mm (deeper is acceptable)
Anchor bolt spacing / projection	110 ±3 mm / 50 +10 / -0 mm
Concrete cover (pad bottom / stem sides)	75 / 40 mm, -10 mm

Records: for each footing (A1 ... F6), keep a photo at H3 (bottom), H4 (rebar) and H5 (backfill), the pour date, and the as-built level. These form part of the as-built documents handed over at completion and support the 5-year installation warranty.

8. Notes

- This note elaborates Attachment E of the signed contract. The footing type, size, depth and materials are unchanged, the footings remain included in the Contract Price, and Clause 2 continues to apply. Floor and ground works are not included (Clause 2, Site).
- Assumed soil: firm natural or properly compacted fill, unit weight at least 1,600 kg/m³ when compacted, no groundwater within 0.65 m during the work, presumed allowable bearing 5 t/m². If site conditions differ, Section 5.4 applies.
- Design references: DPT 1311-50 (wind load on buildings, Thailand); EIT working-stress practice for reinforced concrete and steel; materials per Attachment A (concrete 240 ksc, DB10 SD40, steel tube SS400 equivalent).
- Line spacing B, D and F follows a 1.40 m panel mounting-hole pitch. Confirm it on the delivered panels before set-out.