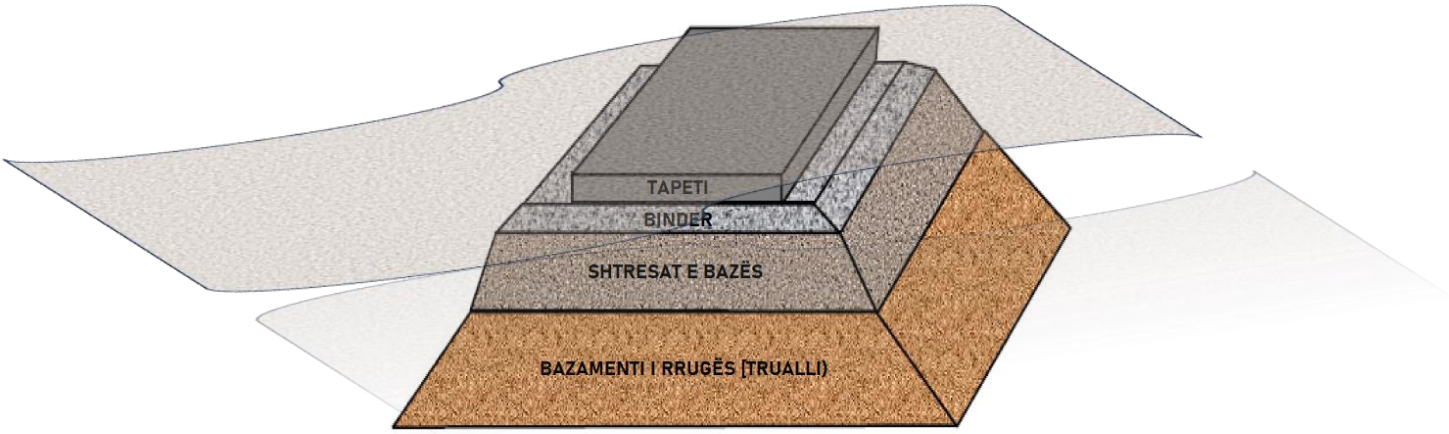
RELACIONI TEKNIK

NDËRTIMI I RRUGËS ZALL BASTAR/VILËZ

AUTORITETI RRUGOR SHQIPTAR

SHTRESAT TIPIKE TË RRUGËS



OBJEKTI: STUDIM - PROJEKTIM “NDËRTIMI I RRUGËS ZALL BASTAR/VILËZ”
FAZA 5 – PROJEKT ZBATIMI

INFRATECH sh.p.k.

Korrik, 2024

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PËRMBAJTJA

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1 TË PËRGJITHSHME

Autoriteti Kontraktues, Bashkia e Tiranës, kërkon të realizojë projektin e zbatimit (studim-projektimi) për objektin: "Ndërtimi i rrugës Zall Bastar/Vilëz", në qytetin e Tiranës, zona e Zall-Bastarit.

Ky relacion teknik, është hartuar në funksion të plotësimit të detyrimit teknik-ligjor për Fazën II të Detyrës së Projektimit, për objektin "Ndërtimi i rrugës Zall-Bastar/ Vilëz" në zbatim të kontratës me titull: Për realizimin e Studim-Projektimit: "Ndërtimi i rrugës Zall Bastar/Vilëz", lidhur ndërmjet Bashkisë Tiranë dhe kompanisë konsulente BOE INFRATECH sh.p.k. & ECG sh.p.k.

1.1 Objektivat

Objekt i projektit do të jetë rehabilitimi i plotë i rrugës me të gjithë elementët e infrastrukturës rrugore, me qëllim përmirësimin e cilësisë së jetës së komunitetit të kësaj zone, konkretisht ndërtimin e shtresave rrugore, trotuareve, ndriçimit, kanalizimet e ujërave të zeza e të bardha, sinjalistikës dhe gjelbërimin.

1.1.1 Kuadri ligjor për fazat e realizimit të Projektit

Realizimi i projektit do të mbështet në fazat e VKM Nr. 354, datë 11.05.2016, Neni 42, Neni 43.

1.1.2 Mbledhja e të dhënave të gjendjes ekzistuese

Zona e propozuar për investim ndodhet në Njësinë Administrative Zall-Bastar/Vilëz, në qytetin e Tiranës. Ky bllok karakterizohet nga ndërtime të natyrave të ndryshme, të realizuara në periudha të ndryshme kohore kryesisht rrugicat dhe rrugët që do trajtohen rrethohen nga objekte të ulta.

Gjendja aktuale është plotësisht jashtë standardeve teknike në fuqi, dhe, një problem tjetër është mungesa e trotuareve dhe hapësirave të mjaftueshme për parkim, gjë që mund të krijojë sfida të kuptueshme për qarkullimin e udhëtarëve si edhe jetëgjatësisë së rrugës. Një tjetër çështje është ndriçimi rrugor, i cili mungon plotësisht, që është plotësisht e pasigurt dhe e pakëndshme për përdoruesit e rrugës. Mungesa e gjelbërimit gjithashtu është një problem, duke u bërë e rëndësishme për të përmirësuar pamjen mjedisore dhe cilësinë e jetës në këtë zonë.

Për të shfrytëzuar potencialin e kësaj zone për investime të suksesshme dhe për të adresuar sfidat e saj aktualisht, është e nevojshme një strategji e qëndrueshme dhe integrale e zhvillimit urban. Kjo mund të përfshijë përmirësimin e infrastrukturës rrugore, përfshirjen e trotuareve dhe hapësirave të mjaftueshme për parkim, modernizimin e ndriçimit rrugor në mënyra të sigurta dhe të efektshme, si dhe investime në gjelbërim dhe hapësira publike. Një qasje e koordinuar dhe e përkushtuar nga autoritetet lokale dhe investitorët mund të ndihmojë në transformimin e kësaj zone në një ambient tërheqës dhe të qëndrueshëm për banorët dhe bizneset.

1.2 Kuadri Ligjor/Teknik – Standardet Rrugore të Projektimit

Projektuesi do të zhvillojë projektimin e këtij rrjeti rrugor sipas standardeve gjeometrike më të fundit dhe me te përshtatshme.

- VKM nr. 628, date 15.07.2015 "Për Miratimin e Rregullave Teknike te Projektimit dhe Ndërtimit te Rrugëve" - Rregullat Teknike të Projektimit te Rrugëve;
- Plani i Përgjithshëm Vendor i Bashkisë Tiranë 14.07.2017;
- Standardet Rrugore Italiane (CNR80, ose DM2001);
- AASHTO, Guide for Design of Pavement Structures 1993 - American Association of State Highway and Transportation Officials;
- Standardet EN dhe DIN – vetëm ato pjesë që kanë harmoni me VKM nr. 628, date 15.07.2015.

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Vlen të theksohet që Rregullat Teknike të Projektimit të Rrugëve, listuar më sipër, përbën bazën e vetme ligjore të aprovuar, nga ku Projektuesi që dimensionon dhe vlerëson dyshemenë e një aksi rrugor brenda kufirit të Shqipërisë, mund të marrë të gjitha formulat dhe parametrat gjeometrike për të përfundimin e projektimit gjeometrik dhe strukturor të një rruge.

Gjithsesi, për tu theksuar gjithashtu, se rrugët që janë nën pronësinë e Njësive Lokale, sidomos ato sekondare nuk janë subjekt i detyrimeve gjeometrike që lindin nga VKM nr. 628, date 15.07.2015, pra rrugët që janë nën pronësinë e bashkive. Kjo lidhet me faktin se çdo Bashki harton një Plan të Përgjithshëm Vendor, pjesë e të cilit është edhe përcaktimi i Rrjetit Rrugor, strukturat e Rrjetit Rrugor si dhe përmasat.

Prandaj meqenëse edhe zhvillimi urban dhe i ndërtimeve ka ndërhyrë jo pak në kufijtë e rrugëve, shpeshherë bëhet e vështirë përzgjedhja e parametrave të duhur për projektimin e një rruge rurale lokale.

1.3 Të përgjithshme – situata faktike

Zona e propozuar për investim ndodhet në Njësinë Administrative Zall-Bastar. Rruga që po merret në studim, është rruga që lidh fshatin Zall-Bastar me fshatin Vilëz. Këto fshatra karakterizohen nga ndërtime të natyrave të ndryshme të realizuara në periudha të ndryshme kohore por kryesisht me ndërtime të realizuara pas viteve 1990, me lartësi 1÷3 kate.

Gjendja aktuale e kësaj rruge ka mungesë të plotë të shtresave asfaltike dhe të kushteve minimale, për të gjithë përdoruesit e rrugës. Ka mungesë të sinjalistikës, dhe në disa raste ka ngushtime dhe kthesa me rreze të ngushta, aspak të favorshme për shikueshmërinë minimale të nevojshme.

1.3.1 Infrastruktura rrugore

Pas inspektimit, konfirmohet mungesa e plotë e infrastrukturës rrugore, me shumë dëmtime dhe gropa pothuajse përgjatë gjithë gjatësisë të trupit të rrugës.

Nga matjet, vlerësohet se segmenti rrugor ka një gjatësi prej rreth 6,000 ml dhe gjerësi që ndryshon nga 3.5m dhe në disa vende shkon deri 5.5 m. Vlen të theksohet, që gjerësia mesatare e rrugës, nuk i plotëson kërkesat minimale për rrugën rurale e tipit F. Gjithashtu, pas këqyrjes në vend përgjatë gjithë gjatësisë së rrugës, konfirmohet se në të gjithë gjatësinë e saj mungojnë trotuaret.

1.3.2 Kanalizimet e ujërave të zeza

Pas këqyrjes në vend përgjatë gjithë gjatësisë së rrugës, konfirmohet se në të gjithë gjatësinë e saj mungojnë ose nuk janë aspak të dukshme elementë ose veprat të K.U.Z. Është akoma në proces bashkëpunimi dhe shkëmbimi i informacionit me UKT, për të kryer verifikimin e rrjetit ekzistues të K.U.Z si edhe gjendja funksionale e tyre nëse ato ekzistojnë në trupin e rrugës.

1.3.3 Kanalizimet e ujërave të bardha

Pas këqyrjes në vend përgjatë gjithë gjatësisë së rrugës, konfirmohet se në të gjithë gjatësinë e saj mungojnë ose nuk janë aspak të dukshme elementë ose veprat të K.U.B. Është akoma në proces bashkëpunimi dhe shkëmbimi i informacionit me UKT, për të kryer verifikimin e rrjetit ekzistues të K.U.B si edhe gjendja funksionale e tyre nëse ato ekzistojnë në trupin e rrugës.

1.3.4 Rrjeti ujësjellësit

Pas këqyrjes në vend përgjatë gjithë gjatësisë së rrugës, konfirmohet se në të gjithë gjatësinë e saj mungojnë ose nuk janë aspak të dukshme elementë ose veprat të rrjeti ujësjellës. Është akoma në proces bashkëpunimi dhe shkëmbimi i informacionit me UKT, për të kryer verifikimin e rrjetit ekzistues të Rrjetit të ujësjellësit si edhe gjendja funksionale e tyre nëse ato ekzistojnë në trupin e rrugës.

1.3.5 Rrjeti i ndriçimit rrugor

Pas këqyrjes në vend përgjatë gjithë gjatësisë së rrugës, konfirmohet se mungon ndriçimi rrugor në të gjithë gjatësinë e rrugës. Është akoma në proces bashkëpunimi dhe shkëmbimi i informacionit me OSHEE, për të kryer verifikimin nëse ka rrjet ekzistues apo linja elektrike nëntokësore si edhe gjendja funksionale e tyre nëse ato ekzistojnë në trupin e rrugës.

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1.3.6 Rrjeti i internet telefonisë

Pas këqyrjes në vend përgjatë gjithë gjatësisë së rrugës, konfirmohet se mungon rrjeti i internet telefonisë në të gjithë gjatësinë e rrugës. Është akoma në proces bashkëpunimi dhe shkëmbimi i informacionit me operatorët e ndryshëm, që veprojnë në zonë, për të kryer verifikimin nëse ka rrjet ekzistues apo linja nëntokësore të internet telefonisë si edhe gjendja funksionale e tyre nëse ato ekzistojnë në trupin e rrugës

1.3.7 Gjelbërimi

Pas këqyrjes në vend përgjatë gjithë gjatësisë së rrugës, konfirmohet se mungon gjelbërimi rrugor në të gjithë gjatësinë e rrugës.

1.3.8 Sinjalistika rrugore

Pas këqyrjes në vend përgjatë gjithë gjatësisë së rrugës, konfirmohet se mungon sinjalistika rrugore, si ajo vertikale ashtu edhe ajo horizontale në të gjithë gjatësinë e rrugës.

1.3.9 Pikat e VGM-së

Pas këqyrjes në vend përgjatë gjithë gjatësisë së rrugës, konfirmohet se mungojnë pikat e koshave të grumbullimit të mbetjeve urbane në të gjithë gjatësinë e rrugës.

1.3.10 Parkingjet

Pas këqyrjes në vend përgjatë gjithë gjatësisë së rrugës, konfirmohet se mungon hapësira e parkingut apo vend-pushimeve në të gjithë gjatësinë e rrugës.

Fig. 1.1: Ortofoto e vitit 2015 – Përvijimi gjatësor ekzistues i rrugës "Zall Bastar - Vilëz"

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Tabela 1.1: Disa foto mbi gjendjen faktike – Rr. "Zall Bastar - Vilëz"

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1.4 Zgjidhjet gjeometrike dhe klasifikimi i profileve tip

Bazuar në këqyrjen dhe vizitat në terren, detyrën e projektimit, kërkesat dhe nevojat për menaxhimin e trafikut të këtyre rrugëve, si edhe gjendjen aktuale, është hartuar me kujdes projektimi gjeometrik dhe strukturor.

Përsa i përket zgjedhjeve gjeometrike dhe përshtatjes së infrastrukturës me rrugën e re, shih Relacionin Teknik, pjesë tërësore e këtij Relacioni strukturor por edhe këtij Projekti në tërësi.

1.5 Klasifikimi rrugor

Nisur nga sa më sipër, standardi i projektimit të rrugës, i përdorur nga Konsulenti si referencë për të gjitha çështjet që lidhen me parametrat gjeometrike dhe përcaktimin e gjurmëve të propozuara të rrugës së bllokut të banimit që shtrihet në rrugën "Zall Bastar/Vilëz"" do të përmbushë të gjitha kërkesat përsa i përket:

- Sigurisë;
- Kapacitetit;
- Sjelljes së Përdoruesve të Rrugës;
- Shpejtësisë së pranuar të Projektimit.

1.6 Elementet gjeometrike të projektimit në plan

1.6.1 Shpejtësia e projektimit

Megjithëse shpejtësia e projektimit dikton gradën maksimale të lakores dhe distancën maksimale të shikueshmërisë për përdorim sa më të sigurt të rrugës, nuk duhet të ketë kufizime ne përdorimin e lakoreve horizontale të sheshta ose distancave më të mëdha të shikimit, ku përmirësime të tilla mund të sigurohen si pjesë e projektimit ekonomik.

Megjithatë, nëse kthesat e sheshta ose seksione tangjente do të inkurajonin shoferët të operonin në shpejtësi më të mëdha sesa ajo e Projektimit, atëherë projektimi i kthesave do të marrë në konsideratë shpejtësinë maksimale të propozuar. Të gjitha karakteristikat gjeometrike, veçanërisht distancat e shikimit në kreshtën e kthesave vertikale duhet të lidhen me shpejtësinë maksimale të propozuar.

1.6.2 Gjurma Horizontale – Varianti përfundimtar

Gjurma horizontale e rrugës duhet të sigurojë përdorim të sigurtë dhe të vazhdueshëm në një shpejtësi projektimi konstante përgjatë gjatësive kryesore të rrugës. Standardet do të aplikohen në çdo kthesë, përveçse kur paraqitet e pamundur dhe në këto raste do të specifikohen arsyet dhe zgjidhja më e mirë e mundshme. Këto standarde do të aplikohen gjithashtu edhe në kryqëzime.

Karakteristikat kryesore në projektimin e gjurmës horizontale janë siguria, profili, tipi i rrugës, shpejtësia e projektuar, karakteristikat gjeoteknike, topografia, kostot e ndërtimit dhe shpronësimit. Në projektim, siguria do të konsiderohet gjithmonë, qoftë në rrugë direkte ose mënyrë indirekte.

Shpejtësia e projektuar, në kthesë, kontrollon distancën e shikimit, por distanca e shikimit duhet marrë në konsideratë bashkë me topografinë sepse shpesh ajo kërkon një rreze më të madhe sesa shpejtësia e projektuar. Të gjithë këta faktorë do të balancohen për të përftuar një gjurmë që optimizon përmbushjen e objektivave të ndryshëm si siguria, kostot, harmonia me konturin natyror të tokës ose me gjendjen faktike të trupit të saj. Gjithashtu, në të njëjtën kohë, të gjithë këta faktorë duhet të jenë të përshtatshëm për kategorinë që është vendosur (ose klasifikimin) për projektimin e rrugës.

Gjurma horizontale do të sigurojë të paktën minimumin e distancës së shikueshmërisë për ndalim për shpejtësinë e zgjedhur të projektit në të gjitha pikat e rrugës.

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1.6.3 Klasifikimi i profilit tip – Rruga Zall Bastar/Vilëz – Varianti përfundimtar

Pavarësisht gjendjes aktuale, përsa i përket funksionit kryesor që do të kryejë kjo rruge në të ardhmen, ajo i përket Kategorisë F - Rrugë Rurale Lokale por e modifikuar që t'i përgjigjet kushteve faktike. Kategoritë e kaluesve që do të lejohet të përdorin këtë rrugë janë:

- Kamionë të tonazheve të larta dhe të ulta;
- Autovetura
- Autobusë - Minibusë;
- Motoçikleta;
- Mjete jo motorike;
- Njerëz.

Bazuar në "Rregulli teknik për projektimin e rrugëve, (RrTPRr-2), Vëllimi 2: Projektimi Gjeometrik", Kapitulli 3.5 – Seksioni rrugor, tek Tabela 3.3: Përbërja e karrexhatës, në mënyrë tabelare po japim të dhënat e përgjithshme të kësaj rruge.

Tabela 1.2: Parametrat e Rr "Zall Bastar/Vilëz" – Varianti përfundimtar

Elementi ose informacioni i nevojshëm	Madhësia	Shpjegime/njësi mbi madhësinë
Klasifikimi rrugës	Kategoria F	Rrugë Urbane Lagje
V_{min}=	25	km/orë
V_{max}=	35	km/orë
Numri korsive=	2	
Gjerësia e korsisë=	2.00	m
Gjerësia e bankinës=	0.5	m
i_c=	2.5%	Pjerrësia tërthore
i_l=	14.5%	Pjerrësia gjatësore maksimale

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1.7 Llogaritja e numrit strukturor

1.7.1 Shtresat rrugore

Llogaritjen e shtresave rrugore do ta bëjmë sipas metodologjisë AASHTO të projektimit të rrugëve. Përvoja ka treguar nga krahasimi i disa metodave për projektimin e shtresave rrugore(metodat empirike tabelore apo metodat e deformacionit) se llogaritja sipas AASHTO-s është më e mira për Shqipërinë dhe duhet të përdoret për përcaktimin e trashësisë së shtresave.

Metoda e projektimit të AASHTO-se është fleksibël dhe projektimi sipas kësaj metodë sjell ekonomizim duke minimizuar transportin e materialeve dhe kostot që e shoqërojnë.

Vlefshmëria e materialeve lokale të ndërtimit, si dhe kërkesat për mirëmbajtje të ardhshme merren parasysh në zgjedhjen e tipit dhe trashësisë se shtresave.

Për projektimin e shtresave rrugore marrim parasysh tre faktorë kryesore :

1. Trafiku
2. Fortësia e tabanit të rrugës
3. Materialet e shtresave

a) Trafiku shprehet në terma të numrit shumator ekuivalent të akseve standarde dhe kërkon njohjen e parametrave të mëposhtëm:

- Fluksi aktual i automjeteve tregtare
- Rritja e ardhshme e trafikut të mjeteve tregtare
- Shpërndarja e ngarkesës aksiale të mjeteve tregtare gjatë gjithë jetës ekonomike të rrugës
- Efektet dëmtuese relative të ngarkesave aksiale të ndryshme

b) Fortësia e tabanit të rrugës

Vlerësimet e fortësisë se tabanit të rrugës bazohen në njohjen e tipit të dheut dhe se si dheu i reagon ndryshimeve të përmbajtjes se lagështisë në kushte ambientale të veçanta dhe kundrejt ngjeshjes. Nga kjo njohuri është bere një vlerësim i fortësisë se tabanit të rrugës në lidhje me përmbajtjen e lagështisë dhe gjendjen e ngjeshjes që ka mundësi të ndodhë në terren.

c) Materialet e shtresave

Cilësia e materialeve të shtresave merret në përputhje me specifikimet teknike.

Për llogaritjen sipas metodologjisë AASHTO, duhet të kemi parasysh disa koncepte si numri strukturor, treguesi CBR në përqindje (kapaciteti mbajtës kalifornian) që shpreh fortësinë e tabanit.

Numri strukturor shprehet si numër pa njësi. Numri strukturor është një numër abstrakt që shpreh fortësinë strukturale të shtresës dhe konvertohet me anën e koeficientëve në trashësi, pra në trashësi të shtresës qarkulluese, shtresës bazë granulare [tipikisht stabilizant] dhe nënshtresës.

Numri struktural $SN = a_1D_1 + a_2m_2D_2 + a_3m_3D_3$ Ku:

D_1 – trashësia e shtresës qarkulluese

D_2 – trashësia e shtresës baze granulare

D_3 – trashësia e shtresës nënbazë

a_1, a_2, a_3 janë koeficientët ku vlerat varen nga cilësitë e materialeve dhe jepen në tabelë;

m_2, m_3 janë koeficientët e filtrimit ku vlerat jepen në tabelë.

1.7.2 Përmasimi i paketës së shtresave rrugore

Përmasimi i paketës së shtresave rrugore ka ndikim të drejtpërdrejt në cilësinë, jetëgjatësinë si dhe koston e objektit. Për të arritur këtë qëllim, synimi i këtij raporti është:

- Llogaritja dhe analiza e faktorëve që ndikojnë në mënyrë të drejtpërdrejt në dimensionimin e shtresave rrugore;
- Përcaktimi i përmasave (trashësisë) së shtresave rrugore;
- Dhënia e rezultateve të llogaritjeve si dhe rekomandimet e komentet e nevojshme, shoqëruar me vizatimet, detajet përkatëse, për të mundësuar ndërtimin e paketës se shtresave rrugore.

Tabela 1.3: Koeficientë që varen nga cilësitë e materialeve

Rregulli teknik për projektimin e rrugëve (RrTPRr-3) – Projektimi i dyshemesë

Shtojca A – Koefiçientët Strukturore

MATERIALI	KOEFICIENTI
Betoni Asfaltik (Sipër 100 ½ mm)	0.44
Betoni Asfaltik (> 100 ½ mm nga sipërfaqja)	0.30
Bazë Gëlqerore e Stabilizuar me Klorur Kalciumi	0.18
Agregat Shisti Silicor i Stabilizuar me Çimento	0.20
Agregat i Thyer i Stabilizuar Çimentoje	0.22
Agregat i Thyer dhe Gëlqeror i Thyer (I Ngjeshur deri në i Densitet të Modifikuar)	0.16
Agregat i Thyer dhe Gëlqeror i Thyer (I ngjeshur deri në 96% të Densitetit të Modifikuar)	0.14
Bazë Agregate Gurore Miniere (I Ngjeshur deri në Densitet të Modifikuar)	0.16
Bazë Agregate Gurore Miniere (I ngjeshur deri në 96% të Densitetit të Modifikuar)	0.12
Asfalt Rëre	0.18
Bazë e Stabilizuar Rëre Bituminoze (150 mm)	0.12
Bazë Agregate Dheu	0.12
Çimento Dheu	0.20
Trajtim Sipërfaqeje (Trepjesësh)	0.20
Bazë Argjile Rëre	0.10
Për Projektim Riveshje:	
Beton Asfaltik i Vjetër	0.30
Beton Çimentoje Portland e Vjetër	0.40

Në llogaritjen e shtresave rrugore me metodën e AASHTO-s përdorim vlerat e CBR, ku midis vlerave të CBR dhe modulit mbetës (resilient) për tabanin ekzistojnë lidhje ose formula të pranuara tashmë në praktikat inxhinierike. CBR, e cila jepet në %, përcaktohet me prova laboratorike sipas një procedure. Me anë të saj gjykohet nëse një bazament është i përshtatshëm ose jo.

Llogaritja a intensitetit të trafikut

- N_k =2, nr i korsive të lëvizjes (pranojmë rruge me dy sense lëvizjeje);
- N_a=400 automjete njësi/dite për të dy drejtimet gjatë vitit të parë të ndërtimit – Mbetet për tu diskutuar me Autoritetin Kontraktor;
- R=5.0% rritja vjetore e nr. të automjeteve
- V=20 vjet, periudha e shfrytëzimit
- F=2.5, faktori i shkatërrimit për aksin standard, marrë në konsiderate për mjetet tregtare.
- CBR per bazamentin, pothuajse në të gjithë gjatësinë, në zonat më të dobëta (min) CBR = 3.0%

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1.7.3 Burimet e informacionit dhe matjet e trafikut

Në mungesë të informacionit mbi volumin e trafikut, është pranuar si numër mesatar të mjeteve qe kalojnë në një ditë (TDM) deri në 1000 mjete, referuar "Rregulli teknik për projektimin e rrugëve" (vëllimi 3) duke arsyetuar se rruga është e kategorisë F, rrugë rurale lokale.

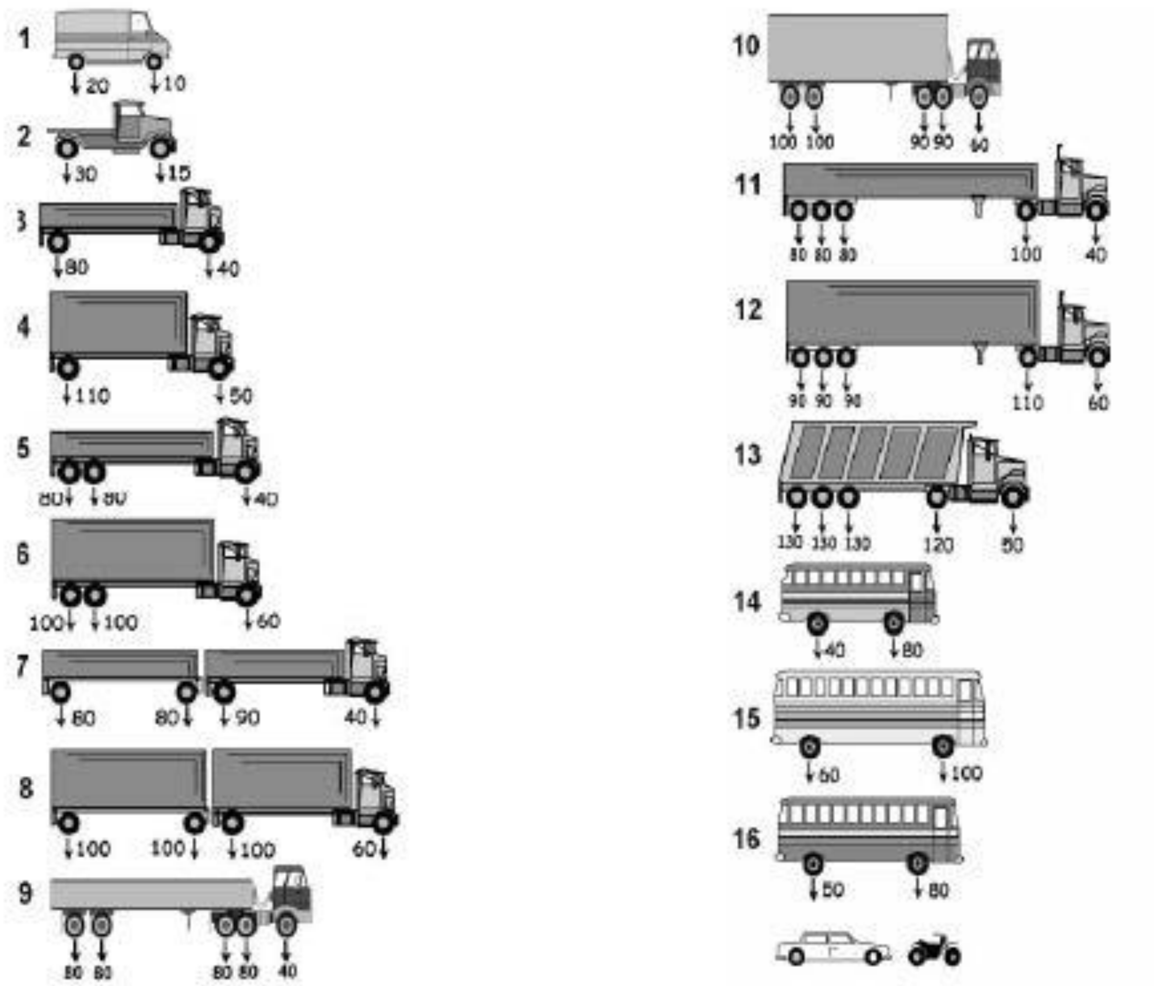

Fig. 1.2: Tipet e mjeteve sipas VKM 628, 2015

Duke iu referuar te dhënave te analizës se flukseve te mjeteve, kemi përpiluar një përmbledhje në lidhje me "spektrin e trafikut". Ky spektër është bërë në bazë të këqyrjeve aktuale, por edhe sipas asaj që parashikohet të lëvizë në këtë segment rrugor bazuar në të dhënat jo-formale marra nga banorët lokalë, sipërmarrjet lokale si edhe të industrive përreth. Mëposhtë jepen kategoritë e mjeteve të marra në konsiderate si dhe spektrin e trafikut.

Vlen të theksohet që lista tipeve te mjeteve sipas VKM 628, 2015 ka ndryshim te vogël me metodën baze për faktin se në këtë normë merren 16 tipe ne krahasim me 14 tipe të AASHTO. Mëposhtë paraqiten lista e tipeve te mjeteve sipas normës, spektri i shpërndarjes se tyre por edhe llogaritjet e bëra hap pas hapi.

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1.8 Shpërndarja faktike e spektrit të trafikut

INFORMACION I PËRGJITHSHËM	
NUMRI RENDOR I PROJEKTIT	002_000
Përshkrimi i Projektit	STUDIM - PROJEKTIM "NDËRTIMI I RRUGËS ZALL BASTAR/VILËZ"
Përshkrimi i Dyshemesë:	Shtresat Asfaltike + Bazat granulare
Kontrolluar nga:	Ing. Rezeart Zgjanjolli

TIPET E MAKINAVE	PËRQINDJET	CURRENT TRAFFIC	GROWTH FACTORS	DESIGN TRAFFIC	E.S.A.L. FACTOR	DESIGN E.S.A.L.	TIPI MJETIT	KOMENTE
MOTOÇIKLETA	2.000	21	33.07	251278	0.0001	25	1	Pranuar minimalisht, në bazë të këqyrjes në fakt, por edhe referuar AASHTO - Rrugë lokale
MAKINA PASAGJERËSH	12.000	125	33.07	1507669	0.0020	3015	2	Pranuar minimalisht, në bazë të këqyrjes në fakt, por edhe referuar AASHTO - Rrugë lokale
KAMIONÇINA	10.000	104	33.07	1256391	0.0389	48874	3	Pranuar minimalisht, në bazë të këqyrjes në fakt, por edhe referuar AASHTO - Rrugë lokale
MAKINA TË MËDHA								
AUTOBUZË	20.000	208	33.07	2512781	0.4111	1033004	4	Pranuar minimalisht, në bazë të këqyrjes në fakt, por edhe referuar AASHTO - Rrugë lokale
MJETE TË PA-ARTIKULUARA								
KAMION 6-RROTA	15.000	156	33.07	1884586	0.2004	377671	5	Pranuar minimalisht, në bazë të këqyrjes në fakt, por edhe referuar AASHTO - Rrugë lokale
KAMIONA ME 3 AKSE	10.000	104	33.07	1256391	1.1384	1430275	6	Pranuar minimalisht, në bazë të këqyrjes në fakt, por edhe referuar AASHTO - Rrugë lokale
KAMIONE ME 4 AKSE	15.000	156	33.07	1884586	3.4784	6555343	7	Pranuar, në bazë të këqyrjes në fakt, përfshirë edhe vetë transportin e makinerive të rënda
MJETE TË ARTIKULUARA								
ME 4 APO MË PAK AKSE	5.000	52	33.07	628195	0.8005	502870	8	Pranuar, në bazë të këqyrjes në fakt, por edhe nga prania e liqenit të Bovillës, potencialit të zhvillimit të turizimit, mundësisë së ndërtimeve
ME 5 AKSE	5.000	52	33.07	628195	1.3377	840337	9	Pranuar, në bazë të këqyrjes në fakt, por edhe nga prania e liqenit të Bovillës, potencialit të zhvillimit të turizimit, mundësisë së ndërtimeve
ME 6 APO MË TEPËR AKSE	0.500	5	33.07	62820	1.2303	77287	10	Pranuar, në bazë të këqyrjes në fakt, por edhe nga prania e liqenit të Bovillës, nevojave të veçanata të mirëmbajtes infrastrukturore
MJETE ME DISA RIMORKIO								
FIVE OR LESS AXLES	5.000	52	33.07	628195	3.0655	1925733	11	Pranuar, në bazë të këqyrjes në fakt, por edhe nga prania e liqenit të Bovillës, potencialit të zhvillimit të turizimit, mundësisë së ndërtimeve
SIX AXLES	0.000	0	33.07	0	2.1102	0	12	
SEVEN OR MORE AXLES	0.000	0	33.07	0	2.1102	0	13	
TË PAKLASIFIKUARA	0.000	0	33.07	0	1.4500	0	14	
SHUMA E TË GJITHA TIPEVE	100	1036				12,794,434 ESALs		

TRAFIKU MESATAR DITOR ADT	1041		
SHPËRNDARJA NË KORSI	100		
KOEF. VJETOR RRITJES SË MAKINA	5.0	20	33.07
GROWTH RATE OF TRUCKS	5.0	20	33.07
	Annual G.Rate in %	Life (yrs)	Growth Factor
G.F. =		((1+g)^n - 1) / g	

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1.9 Llogaritjet analitike të numrit strukturor

1.9.1 Hapat e përmbledhur dhe të dhënat hyrëse/llogaritëse

Tabela 1.4: Koeficientë dhe të dhënat hyrëse/llogaritëse

INFORMACION MBI PROJEKTIN	
Numri Rendor i Projektit	002_000
Qëllimi i Projektit	STUDIM - PROJEKTIM "NDËRTIMI I RRUGËS ZALL BASTAR/VILËZ"
Zonat/Qytetet	Zall Bastar, Tiranë
Përshkrimi i Dyshemesë:	Shtresat Asfaltike + Bazat granulare
Analizuar nga:	Ing. Rezeart Zgjanjolli
Kontrolluar nga:	0
Emri Konsulentit:	INFRATECH sh.p.k.
Emri Rrugës	NDËRTIMI I RRUGËS ZALL BASTAR/VILËZ
Jetëgjatësia Projektuese e Rrugës	20 vite

Legjenda	
(gri)	= llogaritur automatikisht ose vlerë e referncuar (mos predakto)
(jeshile)	= e dhënë hyrëse
(e verdhë)	= zgjidhje(t)
(jeshile e çelët)	= ESAL-ët kumulativë për klasën e përzgjedhur të rrugës
(rozë)	= nuk zbatohet në këtë rast

HAPAT SIPAS VKM 628, 2015		VLERA	NJËSIA	Përshkrime - edhe ANG - për krahasim me AASHTO 1986
Hapi 1: ADT	ADT Totale e trafikut	1,000	mnd (makina në ditë)	Available ADT (Average Daily Traffic) is the measured total volume of vehicle traffic on the subject roadway in *both directions*. The top link, below, contains an interactive AADT map for all roadways in CT that can be used to locate traffic data. The bottom link contains expressway ADT maps for limited access facilities as well as ADT maps for towns. https://portal.ct.gov/DOT/PP_SysInfo/Traffic-Monitoring https://portal.ct.gov/DOT/PP_Bureau/Documents/Maps
	Trafik 2-drejtimësh?	Yes	*(zgjidh YES për trafik me dy drejtime, ose ndryshe NO)*	Please leave this value as "Yes" as the default value for two-way traffic on undivided roadways or if using combined directional data for a divided highway. Otherwise, please select "No" for a one-way road design (ramps, roundabouts, etc.) or if using single direction traffic data for a divided highway (i.e. using northbound data on a N/S expressway). For one-way roads, the ADT will be doubled to account for the default 50% directional distribution assumption of the spreadsheet.
Hapi 2: Viti	Viti $_0$ ADT	2023		Viti kur trafiku mesatar ditor, vihet në dispozicion
	Viti $_{mb}$ Projektit	2025		Viti i mbarimit të Projektimit
Hapi 3: ADT Projektuese		1,040	mnd (makina në ditë)	ADT Projektuese, përdoret si vlera mbi të cilën llogariten ESAL-ët e grumbulluar
Hapi 4: Ngarkesa në Korsinë e Projektimit		100	%	Shpërndarja ose Ngarkesa në Korsinë e Projektimit të propozuar

	% e ESAL-ëve në Korsinë e Projektimit	
Numri i Korsive	CTDOT	AASHTO
2 korsi (1 për drejtim)	100%	100%
4 korsi (2 për drejtim)	90%	80-100%
6+ korsi (3+ për drejtim)	70%	50-80%

Hapi 5: Faktori i Rritjes		5.0	% (makina të voGL)	Faktori i rritjes së numrt të makinave përgjatë viteve të jetëgjatësisë projektuese
		5.0	% (kamionë)	Faktori i rritjes së numrt të të gjitha tipeve të makinerive të rënda përgjatë viteve të jetëgjatësisë projektuese
Hapi 6: Jetëgjatësia Projektimit		20	vite	Period of time for which the pavement design/analysis is to be conducted
Hapi 7: Klasa e Funksionit [Tipi] të Rrugës		Rural Local	*(zgjidh sipas listës së përcaktuar nga AASHTO për secilën tip rruge)*	A roadway functional class (FC) is the designation of a roadway into systems according to the character of service it provides in relation to the total roadway network. Please note that in this case the "Multi-lane" class is equivalent to an interstate highway. The FC maps for each town in Connecticut are found at the link below: https://portal.ct.gov/DOT/PP_SysInfo/Functional-Classification-Maps
Hapi 8: ESAL-ët e Grumbulluar	Rural	12,794,434	ESALs (W18)	Numri i parashikuar i grumbulluar për aksin ekuivalent 80kN përgjatë gjithë viteve të jetëgjatësisë projektuese.
	Urban	FALSE	ESALs (W18)	

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1.9.2 Tabela finale përmbledhëse e rezultateve

Tabela 1.5: Hapat e përmbledhur të llogartijeve

NDËRTIMI I RRUGËS ZALL BASTAR/VILËZ				
Projektimi dyshemesë - Fleksibël				
Rrugë Rurale Lokale				
VKM 2015 - (AASHTO GUIDE FOR THE DESIGN OF PAVEMENT STRUCTURE - 1993)				
A- TË DHËNA MBI PROJEKTIN				
Progresivi: +0.000 deri +16.400	**0.00**			
Viti fillestar që konsiderohet ADT	**2023**			
Viti Përfundimit të Ndërtimit	**2025**			
Viti Parashikuar për Dyshemenë	**2045**			
Kohëzgjatja Projektuese për Dyshemenë	**20**			
B- TË DHËNA PROJEKTUESE				
Ngarkesa e aksit Standard		-	80.00	kN
Niveli Besueshmërisë		R	95.00	%
Treguesi Final i Shërbyeshmërisë		Pt	2.50	-
Treguesi Fillestar i Shërbyeshmërisë		Po	4.20	-
C.B.R. e themelit të rrugës			3.00	%
C- TË DHËNAT E NEVOJSHME PËR LLOGARITJEN E SN				
Nr. i Akseve Ekuivalente për Jetëgjatësinë Projektuese të dhënë më sipër		ESAL	12.79	Milion
Devijimi Standard		S	0.45	-
Devijimi Normale Standard që i përket nivelit të përzgjedhur të besueshmë		Z	-1.65	-
Humbja e Nivelit të Shërbyeshmërisë përgjatë gjithë jetëgjatësisë projektue		PSI	1.70	-
Moduli Llogaritës Mbetës [Rezilient] i Bazamentit të rrugës		MR.	5,161.17	psi
Koeficienti Drenazhit për Bazën Granulare		m_2	1.00	-
Koeficienti Drenazhit për Nën-Bazën Granulare		m_3	1.00	-
Moduli Llogaritës Mbetës [Rezilient] i Asfalt/Binderit		MR.	400,000.00	psi
Moduli Llogaritës Mbetës [Rezilient] i Stabilizantit		MR.	30,000.00	psi
Moduli Llogaritës Mbetës [Rezilient] i Çakëllit/Zhavorrit		MR.	11,000.00	psi
D- NUMRI STRUKTUROR I PROJEKTIMIT (SN) - TOTAL I DYSHEMESË		AnaM	AnaD	
Ana Majtë [AM] = Vlera Log(ESAL) - Ana Djathtë [AD], vlera analitike e Nr. St		7.11	7.17	
Jep një vlerë të përafërt të Numri Strukturor: SN			6.20	OK
E- LLOGARITJET PËR SHTRESAT ASFALTIKE - TAPET		AnaM	AnaD	
NUMRI STRUKTUROR I PROJEKTIMIT (SN) - TAPET		7.11	7.18	
Jep një vlerë të përafërt të Numri Strukturor: SN			3.40	OK
Trashësia minimale, [sipas AASHTO, 1986)		5.00		cm
Trashësia e Tapetit - Asfaltit, D_1		7.73		cm
Koeficienti shtresës së Asfaltit, sipas VKM 628 15.07.2015 SHTOJCA A, a_1		0.44		
Numri Strukturor i Tapetit [Asfaltit]: SN = a_1m_1		3.40		
Trashësia finale e Tapetit, D_1		**8.00**		cm
Numri strukturor final i tapetit asfaltit (SN)		3.52		
F- LLOGARITJET PËR SHTRESAT ASFALTIKE - BINDER		AnaM	AnaD	
NUMRI STRUKTUROR I PROJEKTIMIT (SN) - TAPET+BINDER		7.11	7.18	
Jep një vlerë të përafërt të Numri Strukturor: SN			3.40	OK
Trashësia e Binderit - Asfaltit, D_{1-1}		-0.27		cm
Koeficienti shtresës së Binderit, sipas VKM 628 15.07.2015 SHTOJCA A, a_{1-1}		0.44		
Numri Strukturor i Binderit [Asfaltit]: SN = $a_{1-1}m_{1-1}$		-0.12		
Trashësia finale e Tapetit, D_{1-1}		**9.00**		cm
NUMRI STRUKTUROR FINAL I BINDERIT (SN)		3.96		

Numri Strukturor i Binderit [Asfaltit]: SN = $a_{1-1}m_{1-1}$	-0.12		
Trashësia finale e Tapetit, D_{1-1}	**9.00**		cm
NUMRI STRUKTUROR FINAL I BINDERIT (SN)	3.96		
Numri Strukturor Total i Tapet+Binder [Asfaltit]: SN = $a_1m_1 + a_{1-1}m_{1-1}$	7.48		
G- LLOGARITJET PËR SHTRESËN E STABILIZANTIT/KONGLOMERATIT	AnaM	AnaD	
NUMRI STRUKTUROR I PROJEKTIMIT (SN) - STABILIZANTI	7.11	7.12	
Jep një vlerë të përafërt të Numri Strukturor: SN		4.80	OK
Trashësia minimale, [sipas AASHTO, 1986)	10.00		cm
Trashësia e shtresës së Stabilizantit [96%], D_2	9.14		cm
Koeficienti shtresës së Stabilizantit [96%], VKM 628 15.07.2015 SHTOJCA A,	0.14		
Numri Strukturor shtresës së Stabilizantit [96%]: SN = a_2m_2	1.28		
Trashësia finale e Bazës Granulare [Stabilizant], D_2	**10.00**		cm
NUMRI STRUKTUROR FINAL I STABILIZANTIT (SN)	1.40		
Numri Strukturor Total: SN = $a_1m_1 + a_{1-1}m_{1-1} + a_2m_2$	8.88		
H- LLOGARITJET PËR SHTRESËN E NËNBAZËS [ÇAKËLL]	AnaM	AnaD	
NUMRI STRUKTUROR I PROJEKTIMIT (SN) - NËNBAZA	7.11	7.12	
Jep një vlerë të përafërt të Numri Strukturor: SN		6.10	OK
Trashësia e shtresës së Nënbazës [çakëll, 96%], D_3	9.83		cm
Koeficienti shtresës së NënBazës [96%), VKM 628 15.07.2015 SHTOJCA A, a	0.12		
Numri Strukturor shtresës së Çakëll [96%]: SN = a_2m_2	1.18		
Trashësia finale e NënBazës [Çakëll], D_3	**10.00**		cm
NUMRI STRUKTUROR FINAL I ÇAKËLL (SN)	1.20		
Numri Strukturor Total i DYSHEMESË: SN = $a_1m_1 + a_{1-1}m_{1-1} + a_2m_2 + a_3m_3$		10.08	OK

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1.9.3 Tabela e propozimit final

STUDIM – PROJEKTIM “NDËRTIMI I RRUGËS ZALL BASTAR/VILËZ”						
Shtresat Asfaltike + Bazat granulare						
Zall Bastar, Tiranë						
INFRATECH sh.p.k.						
Progresivi: +0.000 deri +16.400						
Viti fillestar që konsiderohet ADT	2023					
Viti përfundimit punimeve	2025					
Viti përfundimit performancës proje	2045					
Koha e Projektimit, vite	20					
ADT Projektimit, Fillimi Punimeve	1,040					
Tipi rrugës [Pranuar]	Rural Local					
Nr. Total i ESAL	12,794,434					
LLOGARITJET PARAPRAKE						
SHTRESAT:	Shtresa Coeff.	Drenazhi Coeff.	Trash. Shtresës (cm.)	Numri Strukturor SN		
				Faktik	Kumul.	Min. Kërkuar
1. Tapeti	0.44	-	8.00	3.52	3.52	
2. Binder	0.44	-	9.00	3.96	7.48	
3. Stabilizant	0.14	1.00	10.00	1.40	8.88	
4. Çakëll, ose – Baza granulare	0.12	1.00	10.00	1.20	10.08	9.26
						OK
DYSHEMEJA PROPOZUAR						
SHTRESAT:	Shtresa Coeff.	Drenazhi Coeff.	Trash. Shtresës (cm.)	Numri Strukturor SN		
				Faktik	Kumul.	Min. Kërkuar
1. Tapeti	0.44	-	4.00	1.76	1.76	
2. Binder	0.44	-	6.00	2.64	4.4	
3. Stabilizant	0.14	1.00	10.00	1.40	5.8	
4. Çakëll, ose – Baza granulare	0.12	1.00	30.00	3.60	9.4	9.26
						OK

Në funksion të numri strukturor, vlerësuar me tentativa, Sn=9.26 (Numri strukturor i kërkuar), paketa e parashikuar e shtresave në rrugët kryesore:

Përshkrimi	**Trashësia**	**Nr. Strukturor**
1. Asfaltobeton	4 cm	1.76
2. Binder	6 cm	2.64
3. Stabilizant	10 cm	1.40
4. Çakëll	2x15 cm	3.60

Nga kjo strukturë e pranuar për trupin e rrugës, rezulton, Numri strukturor i projektuar SN= 9.40.

Gjithashtu, pjesë tërësore e këtij Relacioni strukturor, janë edhe Anekset me llogaritjen e qëndrueshmërisë të mureve mbajtëse me gabion, Aneksi 1, Aneksi 2 dhe Aneksi 3.

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[16] Aneksi 2- ZALL BASTAR_Analiza murit me gabion - 4 nivele;
[17] Aneksi 3- ZALL BASTAR_Analiza murit me gabion - 5 nivele.

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GABION RETAINING WALL ANLYSIS & DESIGN

In accordance with EN 1997-1:2004 - Code of Practice for Geotechnical design and the recommended values

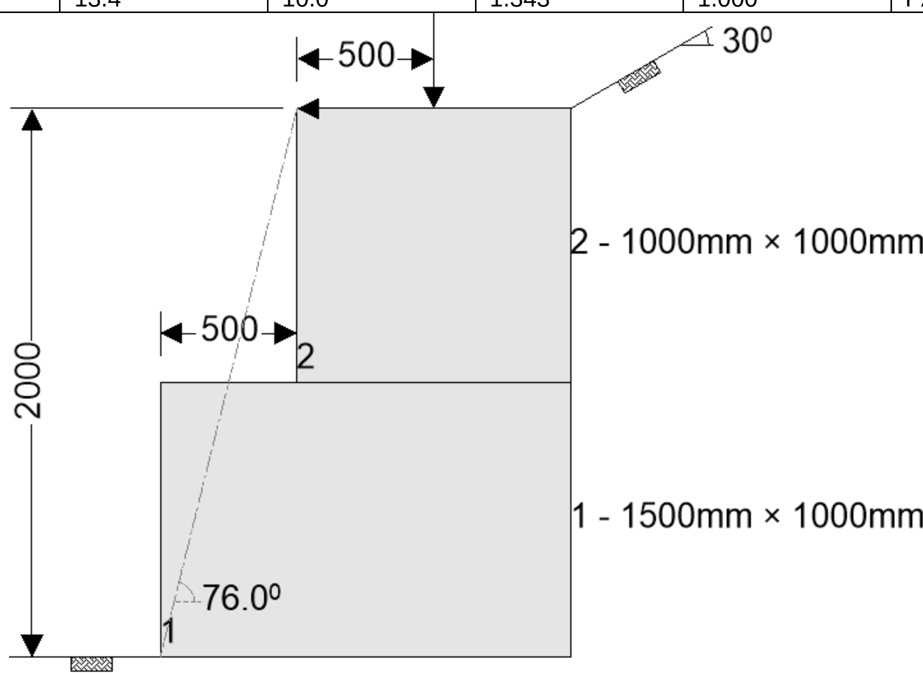
Design summary

Combination 1

Action	Resistance	Force	FoS	Allowable FoS	Status
Overturning, sliding and bearing at base level					
Overturning (kNm/m)	58.6	31.4	1.868	1.000	PASS
Sliding (kN/m)	33.5	44.0	1.761	1.000	PASS
Bearing (kN/m^2)	150.0	59.9	2.503	1.000	PASS
Eccentricity (mm)	Reaction acts within the middle third of base				PASS
Overturning and sliding between courses 1 and 2					
Overturning (kNm/m)	13.8	5.0	2.729	1.000	PASS
Sliding (kN/m)	17.0	12.1	1.400	1.000	PASS

Combination 2

Action	Resistance	Force	FoS	Allowable FoS	Status
Overturning, sliding and bearing at base level					
Overturning (kNm/m)	56.2	25.7	2.189	1.000	PASS
Sliding (kN/m)	26.1	35.9	1.726	1.000	PASS
Bearing (kN/m^2)	150.0	59.9	2.503	1.000	PASS
Eccentricity (mm)	Reaction acts within the middle third of base				PASS
Overturning and sliding between courses 1 and 2					
Overturning (kNm/m)	13.4	4.2	3.194	1.000	PASS
Sliding (kN/m)	13.4	10.0	1.343	1.000	PASS



Wall geometry

Width of gabion 1; w_1 = **1500** mm

Height of gabion 1; h_1 = **1000** mm

Width of gabion 2; w_2 = **1000** mm

Height of gabion 2; h_2 = **1000** mm

Step to front face between courses 1 and 2; s_2 = **500** mm

Wall inclination; ε = **0** deg

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Gabion properties

Unit weight of fill; γ_d = **16.0** kN/m^3

Friction between gabions; $\delta_{bg.k}$ = **35.0** deg

Loading

Permanent horizontal line load; $F_{h,G}$ = **0** kN/m

Variable horizontal line load; $F_{h,Q}$ = **1** kN/m

Vertical height of horizontal load from top gabion; H_{hl} = **0** mm

Dist of horiz. load from leading edge of top gabion; D_{hl} = **0** mm

Permanent vertical line load; $F_{v,G}$ = **5** kN/m

Variable vertical line load; $F_{v,Q}$ = **2** kN/m

Dist of vert. load from leading edge of top gabion; D_{vl} = **500** mm

Soil properties

Slope of retained soil; β = **30.0** deg

Characteristic effective shearing resistance angle; $\phi'_{r.k}$ = **30.0** deg

Characteristic saturated density of retained soil; γ_{sr} = **21.0** kN/m^3

Coefficient for wall friction; $k_{membrane}$ = **0.75**

Wall friction angle; $\delta_{r.k}$ = **22.5** deg

Characteristic base friction angle; $\delta_{bb.k}$ = **30.0** deg

Bearing capacity of founding soil; q = **150** kN/m^2

Wall geometry

Horizontal distance to centre of gravity gabion 1; $x_{g1} = w_1 / 2 =$ **750** mm

Vertical distance to centre of gravity gabion 1; $y_{g1} = h_1 / 2 =$ **500** mm

Weight of gabion 1; $W_{g1} = \gamma_d \times w_1 \times h_1 =$ **24.0** kN/m

Horizontal distance to centre of gravity gabion 2; $x_{g2} = w_2 / 2 + s_2 =$ **1000** mm

Vertical distance to centre of gravity gabion 2; $y_{g2} = h_2 / 2 + h_1 =$ **1500** mm

Weight of gabion 2; $W_{g2} = \gamma_d \times w_2 \times h_2 =$ **16.0** kN/m

Weight of entire gabion; $W_g = W_{g1} + W_{g2} =$ **40.0** kN/m

Horiz distance to centre of gravity entire gabion; $x_g = ((W_{g1} \times x_{g1}) + (W_{g2} \times x_{g2})) / W_g =$ **850** mm

Vert distance to centre of gravity entire gabion; $y_g = ((W_{g1} \times y_{g1}) + (W_{g2} \times y_{g2})) / W_g =$ **900** mm

Correcting for wall inclination horiz dist; $X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) =$ **850** mm

Vertical change in height due to wall inclination; $H_f = y_{g2} + h_2/2 - ((y_{g2} + h_2/2) \times \cos(\varepsilon) - (x_{g2} + w_2/2) \times \sin(\varepsilon)) =$ **0** mm

Design dimensions

Effective angle of rear plane of wall; $\alpha = 90 \text{ deg} + \varepsilon =$ **90.0** deg

Effective face angle; $\theta = \text{Atan}((y_{g2} + (h_2 / 2)) / ((x_{g2} - (w_2 / 2)))) - \varepsilon =$ **76.0** deg

Effective height of wall; $H = (y_{g2} + h_2 / 2) + (w_1 \times \sin(\varepsilon)) - H_f =$ **2000** mm

Height of wall from toe to front edge of top gabion; $H_{incl} = ((y_{g2} + h_2 / 2) \times \cos(\varepsilon) - (x_{g2} - (w_2 / 2)) \times \sin(\varepsilon)) =$ **2000**mm

Active pressure using Coulomb theory; $K_a = \sin(\alpha + \phi'_{r.k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.k}) \times (1 + \sqrt{(\sin(\phi'_{r.k} + \delta_{r.k}) \times \sin(\phi'_{r.k} - \beta) / (\sin(\alpha - \delta_{r.k}) \times \sin(\alpha + \beta))))^2) =$ **0.812**

Active thrust due to soil; $P_{a,soil} = 0.5 \times K_a \times \gamma_{sr} \times H^2 =$ **34.1** kN/m

Pressure at base

Horizontal forces

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Retained soil; $F_{soil\_h,q} = P_{a,soil} \times \cos(90 - \alpha + \delta_{r.k}) =$ **31.5** kN/m

Height of soil thrust resolved vertically; $d_{h,soil} = H / 3 - w_1 \times \sin(\varepsilon) =$ **667** mm

Line loading; $F_{line\_h,q} = F_{h,Q} =$ **1.0** kN/m

Vertical distance to where load acts; $d_{h,line} = H_{incl} + H_{hl} - D_{hl} \times \tan(\varepsilon) = \mathbf{2000}$ mm

Vertical forces

Gabion weight; $F_{gabion\_v,q} = W_g = \mathbf{40.0}$ kN/m

Retained soil; $F_{soil\_v,q} = P_{a,soil} \times \sin(90 - \alpha + \delta_{r.k}) = \mathbf{13.0}$ kN/m

Horizontal dist to where soil thrust acts; $b_{v,soil} = w_1 \times \cos(\varepsilon) - (H / 3) / \tan(\alpha) = \mathbf{1500}$ mm

Line loading; $F_{line\_v,q} = (F_{v,G} + F_{v,Q}) = \mathbf{7.0}$ kN/m

Horizontal distance to where load acts; $b_{v,line} = H_{incl} / \tan(\theta) + D_{vl} = \mathbf{1000}$ mm

Total horizontal unfactored force; $T_q = F_{soil\_h,q} + F_{line\_h,q} = \mathbf{32.5}$ kN/m

Total vertical unfactored force; $N_q = F_{gabion\_v,q} + F_{soil\_v,q} + F_{line\_v,q} = \mathbf{60.0}$ kN/m

Force normal to base; $N_s = N_q \times \cos(\varepsilon) + T_q \times \sin(\varepsilon) = \mathbf{60.0}$ kN/m

Total unfactored overturning force; $M_{o,q} = F_{soil\_h,q} \times d_{h,soil} + F_{line\_h,q} \times d_{h,line} = \mathbf{23.0}$ kNm/m

Total unfactored restoring force; $M_{R,q} = F_{gabion\_v,q} \times X_g + F_{soil\_v,q} \times b_{v,soil} + F_{line\_v,q} \times b_{v,line} = \mathbf{60.6}$ kNm/m

Eccentricity; $e = w_1 / 2 - (M_{R,q} - M_{o,q}) / N_s = \mathbf{124}$ mm

Reaction acts within middle third of base

Pressure at toe; $\sigma_{toe} = N_s / w_1 \times (1 + (6 \times e / w_1)) = \mathbf{59.9}$ kN/m^2

Pressure at heel; $\sigma_{heel} = N_s / w_1 \times (1 - (6 \times e / w_1)) = \mathbf{20.1}$ kN/m^2

Factor of safety; $FoS_Q = q / \max(\sigma_{toe}, \sigma_{heel}) = \mathbf{2.503}$

Allowable factor of safety; $FoS_{Q\_allow} = \mathbf{1.000}$

PASS - Design FoS for allowable bearing pressure exceeds min allowable pressure to base

Design approach 1

Partial factors on actions - Section A.3.1 - Combination 1

Permanent unfavourable action; $\gamma_G = \mathbf{1.35}$

Permanent favourable action; $\gamma_{G,f} = \mathbf{1.00}$

Variable unfavourable action; $\gamma_Q = \mathbf{1.50}$

Variable favourable action; $\gamma_{Q,f} = \mathbf{0.00}$

Partial factors for soil parameters - Section A.3.2 - Combination 1

Angle of shearing resistance; $\gamma_{\phi'} = \mathbf{1.00}$

Weight density; $\gamma_\gamma = \mathbf{1.00}$

Design soil properties

Design effective shearing resistance angle; $\phi'_{r.d} = \mathrm{Atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'}) = \mathbf{30.0}$ deg

Design saturated density of retained soil; $\gamma_{s.d} = \gamma_{sr} / \gamma_\gamma = \mathbf{21.0}$ kN/m^3

Design wall friction angle; $\delta_{r.d} = \min(\mathrm{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'}), \phi'_{r.d} \times k_{membrane}) = \mathbf{22.5}$ deg

Design base friction angle; $\delta_{bb.d} = \mathrm{Atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'}) = \mathbf{30.0}$ deg

Design friction between gabions; $\delta_{bg.d} = \mathrm{Atan}(\tan(\delta_{bg.k}) / \gamma_{\phi'}) = \mathbf{35.0}$ deg

Active pressure using Coulomb theory; $K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d})) = \mathbf{0.812}$

Active thrust due to soil; $P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2 = \mathbf{34.1}$ kN/m

Horizontal forces

Retained soil; $F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d}) = \mathbf{42.5}$ kN/m

Line loading; $F_{line\_h} = F_{h,Q} \times \gamma_Q = \mathbf{1.5}$ kN/m

Vertical forces

Gabion weight; $F_{gabion\_v,f} = \gamma_{G,f} \times W_g = \mathbf{40.0}$ kN/m

Retained soil; $F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d}) = \mathbf{13.0}$ kN/m

Line loading; $F_{line\_v,f} = (F_{v,G} \times \gamma_{G,f} + F_{v,Q} \times \gamma_{Q,f}) = \mathbf{5.0}$ kN/m

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Overturning stability - take moments about the toe

Overturning moment; $M_o = F_{soil\_h} \times d_{h,soil} + F_{line\_h} \times d_{h,line} = \mathbf{31.4}$ kNm/m

Restoring moment; $M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{line\_v,f} \times b_{v,line} = \mathbf{58.6}$ kNm/m

Factor of safety; $FoS_M = M_R / M_o = \mathbf{1.868}$

Allowable factor of safety; $FoS_{M\_allow} = \mathbf{1.000}$

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force; $T = F_{soil\_h} + F_{line\_h} = \mathbf{44.0}$ kN/m

Total vertical force; $N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{line\_v,f} = \mathbf{58.0}$ kN/m

Sliding force; $F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) = \mathbf{44.0}$ kN/m

Sliding resistance; $F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bb.d}) = 42.2$ kN/m

Factor of safety; $FoS_S = F_R / F_f = \mathbf{1.761}$

Allowable factor of safety; $FoS_{S\_allow} = \mathbf{1.000}$

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

<u>Check overturning and sliding between courses 1 and 2</u>

Wall geometry

Horizontal distance to centre of gravity gabion 2; $x_{g2} = w_2 / 2 = \mathbf{500}$ mm

Vertical distance to centre of gravity gabion 2; $y_{g2} = h_2 / 2 = \mathbf{500}$ mm

Weight of gabion 2; $W_{g2} = \gamma_d \times w_2 \times h_2 = \mathbf{16.0}$ kN/m

Weight of entire gabion; $W_g = W_{g2} = \mathbf{16.0}$ kN/m

Horiz distance to centre of gravity entire gabion; $x_g = ((W_{g2} \times x_{g2})) / W_g = \mathbf{500}$ mm

Vert distance to centre of gravity entire gabion; $y_g = ((W_{g2} \times y_{g2})) / W_g = \mathbf{500}$ mm

Correcting for wall inclination horiz dist; $X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) = \mathbf{500}$ mm

Vertical change in height due to wall inclination; $H_f = y_{g2} + h_2/2 - ((y_{g2} + h_2/2) \times \cos(\varepsilon) - (x_{g2} + w_2/2) \times \sin(\varepsilon)) = \mathbf{0}$ mm

Design dimensions

Effective angle of rear plane of wall; $\alpha = 90\text{ deg} + \varepsilon = \mathbf{90.0}$ deg

Effective face angle; $\theta = 90\text{deg} - \varepsilon = \mathbf{90.0}$ deg

Effective height of wall; $H = (y_{g2} + h_2 / 2) + (w_2 \times \sin(\varepsilon)) - H_f = \mathbf{1000}$ mm

Height of wall from toe to front edge of top gabion; $H_{incl} = ((y_{g2} + h_2 / 2) \times \cos(\varepsilon) - (x_{g2} - (w_2 / 2)) \times \sin(\varepsilon)) = \mathbf{1000}$mm

Active pressure using Coulomb theory; $K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d})) = \mathbf{0.812}$

Active thrust due to soil; $P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2 = \mathbf{8.5}$ kN/m

Horizontal forces

Retained soil; $F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d}) = \mathbf{10.6}$ kN/m

Line loading; $F_{line\_h} = F_{h,Q} \times \gamma_Q = \mathbf{1.5}$ kN/m

Vertical forces

Gabion weight; $F_{gabion\_v,f} = \gamma_{G,f} \times W_g = \mathbf{16.0}$ kN/m

Retained soil; $F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d}) = \mathbf{3.3}$ kN/m

Line loading; $F_{line\_v,f} = (F_{v,G} \times \gamma_{G,f} + F_{v,Q} \times \gamma_{Q,f}) = \mathbf{5.0}$ kN/m

Overturning stability - take moments about the toe

Overturning moment; $M_o = F_{soil\_h} \times d_{h,soil} + F_{line\_h} \times d_{h,line} = \mathbf{5.0}$ kNm/m

Restoring moment; $M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{line\_v,f} \times b_{v,line} = \mathbf{13.8}$ kNm/m

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Factor of safety; $FoS_M = M_R / M_o = \mathbf{2.729}$

Allowable factor of safety; $FoS_{M\_allow} = \mathbf{1.000}$

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force; $T = F_{soil\_h} + F_{line\_h} =$ **12.1** kN/m

Total vertical force; $N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{line\_v,f} =$ **24.3** kN/m

Sliding force; $F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) =$ **12.1** kN/m

Sliding resistance; $F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bg.d}) =$ **17.0** kN/m

Factor of safety; $FoS_S = F_R / F_f =$ **1.400**

Allowable factor of safety; $FoS_{S\_allow} =$ **1.000**

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

Design approach 1

Partial factors on actions - Section A.3.1 - Combination 2

Permanent unfavourable action; $\gamma_G =$ **1.00**

Permanent favourable action; $\gamma_{G,f} =$ **1.00**

Variable unfavourable action; $\gamma_Q =$ **1.30**

Variable favourable action; $\gamma_{Q,f} =$ **0.00**

Partial factors for soil parameters - Section A.3.2 - Combination 2

Angle of shearing resistance; $\gamma_{\phi'} =$ **1.25**

Weight density; $\gamma_\gamma =$ **1.00**

Design soil properties

Design effective shearing resistance angle; $\phi'_{r.d} = \mathrm{Atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'}) =$ **24.8** deg

Design saturated density of retained soil; $\gamma_{s.d} = \gamma_{sr} / \gamma_\gamma =$ **21.0** kN/m³

Design wall friction angle; $\delta_{r.d} = \min(\mathrm{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'}), \phi'_{r.d} \times k_{membrane}) =$ **18.3** deg

Design base friction angle; $\delta_{bb.d} = \mathrm{Atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'}) =$ **24.8** deg

Design friction between gabions; $\delta_{bg.d} = \mathrm{Atan}(\tan(\delta_{bg.k}) / \gamma_{\phi'}) =$ **29.3** deg

Wall geometry

Horizontal distance to centre of gravity gabion 1; $x_{g1} = w_1 / 2 =$ **750** mm

Vertical distance to centre of gravity gabion 1; $y_{g1} = h_1 / 2 =$ **500** mm

Weight of gabion 1; $W_{g1} = \gamma_d \times w_1 \times h_1 =$ **24.0** kN/m

Horizontal distance to centre of gravity gabion 2; $x_{g2} = w_2 / 2 + s_2 =$ **1000** mm

Vertical distance to centre of gravity gabion 2; $y_{g2} = h_2 / 2 + h_1 =$ **1500** mm

Weight of gabion 2; $W_{g2} = \gamma_d \times w_2 \times h_2 =$ **16.0** kN/m

Weight of entire gabion; $W_g = W_{g1} + W_{g2} =$ **40.0** kN/m

Horiz distance to centre of gravity entire gabion; $x_g = ((W_{g1} \times x_{g1}) + (W_{g2} \times x_{g2})) / W_g =$ **850** mm

Vert distance to centre of gravity entire gabion; $y_g = ((W_{g1} \times y_{g1}) + (W_{g2} \times y_{g2})) / W_g =$ **900** mm

Correcting for wall inclination horiz dist; $X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) =$ **850** mm

Vertical change in height due to wall inclination; $H_f = y_{g2} + h_2/2 - ((y_{g2} + h_2/2) \times \cos(\varepsilon) - (x_{g2} + w_2/2) \times \sin(\varepsilon)) =$ **0** mm

Design dimensions

Effective angle of rear plane of wall; $\alpha = 90 \text{ deg} + \varepsilon =$ **90.0** deg

Effective face angle; $\theta = \mathrm{Atan}((y_{g2} + (h_2 / 2)) / ((x_{g2} - (w_2 / 2)))) - \varepsilon =$ **76.0** deg

Effective height of wall; $H = (y_{g2} + h_2 / 2) + (w_1 \times \sin(\varepsilon)) - H_f =$ **2000** mm

Height of wall from toe to front edge of top gabion; $H_{incl} = ((y_{g2} + h_2 / 2) \times \cos(\varepsilon) - (x_{g2} - (w_2 / 2)) \times \sin(\varepsilon)) =$ **2000**mm

Active pressure using Coulomb theory; $K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d})) =$ **0.868**

Active thrust due to soil; $P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2 =$ **36.5** kN/m

Horizontal forces

Retained soil; $F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d}) =$ **34.6** kN/m

Line loading; $F_{line\_h} = F_{h,Q} \times \gamma_Q = \mathbf{1.3}$ kN/m

Vertical forces

Gabion weight; $F_{gabion\_v,f} = \gamma_{G,f} \times W_g = \mathbf{40.0}$ kN/m

Retained soil; $F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d}) = \mathbf{11.5}$ kN/m

Line loading; $F_{line\_v,f} = (F_{v,G} \times \gamma_{G,f} + F_{v,Q} \times \gamma_{Q,f}) = \mathbf{5.0}$ kN/m

Overturning stability - take moments about the toe

Overturning moment; $M_o = F_{soil\_h} \times d_{h,soil} + F_{line\_h} \times d_{h,line} = \mathbf{25.7}$ kNm/m

Restoring moment; $M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{line\_v,f} \times b_{v,line} = \mathbf{56.2}$ kNm/m

Factor of safety; $FoS_M = M_R / M_o = \mathbf{2.189}$

Allowable factor of safety; $FoS_{M\_allow} = \mathbf{1.000}$

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force; $T = F_{soil\_h} + F_{line\_h} = \mathbf{35.9}$ kN/m

Total vertical force; $N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{line\_v,f} = \mathbf{56.5}$ kN/m

Sliding force; $F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) = \mathbf{35.9}$ kN/m

Sliding resistance; $F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bb.d}) = \mathbf{62.0}$ kN/m

Factor of safety; $FoS_S = F_R / F_f = \mathbf{1.726}$

Allowable factor of safety; $FoS_{S\_allow} = \mathbf{1.000}$

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

<u>Check overturning and sliding between courses 1 and 2</u>

Wall geometry

Horizontal distance to centre of gravity gabion 2; $x_{g2} = w_2 / 2 = \mathbf{500}$ mm

Vertical distance to centre of gravity gabion 2; $y_{g2} = h_2 / 2 = \mathbf{500}$ mm

Weight of gabion 2; $W_{g2} = \gamma_d \times w_2 \times h_2 = \mathbf{16.0}$ kN/m

Weight of entire gabion; $W_g = W_{g2} = \mathbf{16.0}$ kN/m

Horiz distance to centre of gravity entire gabion; $x_g = ((W_{g2} \times x_{g2})) / W_g = \mathbf{500}$ mm

Vert distance to centre of gravity entire gabion; $y_g = ((W_{g2} \times y_{g2})) / W_g = \mathbf{500}$ mm

Correcting for wall inclination horiz dist; $X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) = \mathbf{500}$ mm

Vertical change in height due to wall inclination; $H_f = y_{g2} + h_2/2 - ((y_{g2} + h_2/2) \times \cos(\varepsilon) - (x_{g2} + w_2/2) \times \sin(\varepsilon)) = \mathbf{0}$ mm

Design dimensions

Effective angle of rear plane of wall; $\alpha = 90 \text{ deg} + \varepsilon = \mathbf{90.0}$ deg

Effective face angle; $\theta = 90\text{deg} - \varepsilon = \mathbf{90.0}$ deg

Effective height of wall; $H = (y_{g2} + h_2 / 2) + (w_2 \times \sin(\varepsilon)) - H_f = \mathbf{1000}$ mm

Height of wall from toe to front edge of top gabion; $H_{incl} = ((y_{g2} + h_2 / 2) \times \cos(\varepsilon) - (x_{g2} - (w_2 / 2)) \times \sin(\varepsilon)) = \mathbf{1000}$mm

Active pressure using Coulomb theory; $K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d})) = \mathbf{0.868}$

Active thrust due to soil; $P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2 = \mathbf{9.1}$ kN/m

Horizontal forces

Retained soil; $F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d}) = \mathbf{8.7}$ kN/m

Line loading; $F_{line\_h} = F_{h,Q} \times \gamma_Q = \mathbf{1.3}$ kN/m

Vertical forces

Gabion weight; $F_{gabion\_v,f} = \gamma_{G,f} \times W_g = \mathbf{16.0}$ kN/m

Retained soil; $F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d}) = \mathbf{2.9}$ kN/m

Line loading; $F_{line\_v,f} = (F_{v,G} \times \gamma_{G,f} + F_{v,Q} \times \gamma_{Q,f}) = \mathbf{5.0}$ kN/m

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Overturning stability - take moments about the toe

Overturning moment; $M_o = F_{soil\_h} \times d_{h,soil} + F_{line\_h} \times d_{h,line}$ = **4.2** kNm/m

Restoring moment; $M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{line\_v,f} \times b_{v,line}$ = **13.4** kNm/m

Factor of safety; $FoS_M = M_R / M_o$ = **3.194**

Allowable factor of safety; FoS_{M_allow} = **1.000**

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force; $T = F_{soil\_h} + F_{line\_h}$ = **10.0** kN/m

Total vertical force; $N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{line\_v,f}$ = **23.9** kN/m

Sliding force; $F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon)$ = **10.0** kN/m

Sliding resistance; $F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bg.d})$ = **13.4** kN/m

Factor of safety; $FoS_S = F_R / F_f$ = **1.343**

Allowable factor of safety; FoS_{S_allow} = **1.000**

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

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GABION RETAINING WALL ANLYSIS & DESIGN

In accordance with EN 1997-1:2004 - Code of Practice for Geotechnical design and the recommended values

Design summary

Combination 1

Action	Resistance	Force	FoS	Allowable FoS	Status
Overturning, sliding and bearing at base level					
Overturning (kNm/m)	229.6	88.8	2.586	1.000	PASS
Sliding (kN/m)	78.5	63.6	1.235	1.000	PASS
Bearing (kN/m^2)	150.0	59.3	2.529	1.000	PASS
Eccentricity (mm)	Reaction acts within the middle third of base				PASS
Overturning and sliding between courses 1 and 2					
Overturning (kNm/m)	114.9	39.4	2.915	1.000	PASS
Sliding (kN/m)	61.4	36.4	1.686	1.000	PASS
Overturning and sliding between courses 2 and 3					
Overturning (kNm/m)	46.1	13.3	3.457	1.000	PASS
Sliding (kN/m)	34.8	17.0	2.047	1.000	PASS
Overturning and sliding between courses 3 and 4					
Overturning (kNm/m)	11.7	2.8	4.185	1.000	PASS
Sliding (kN/m)	15.5	5.4	2.888	1.000	PASS

Combination 2

Action	Resistance	Force	FoS	Allowable FoS	Status
Overturning, sliding and bearing at base level					
Overturning (kNm/m)	229.8	82.1	2.799	1.000	PASS
Sliding (kN/m)	62.9	59.0	1.066	1.000	PASS
Bearing (kN/m^2)	150.0	59.3	2.529	1.000	PASS
Eccentricity (mm)	Reaction acts within the middle third of base				PASS
Overturning and sliding between courses 1 and 2					
Overturning (kNm/m)	115.0	36.3	3.165	1.000	PASS
Sliding (kN/m)	49.2	33.7	1.457	1.000	PASS
Overturning and sliding between courses 2 and 3					
Overturning (kNm/m)	46.2	12.2	3.781	1.000	PASS
Sliding (kN/m)	27.9	15.7	1.774	1.000	PASS
Overturning and sliding between courses 3 and 4					
Overturning (kNm/m)	11.7	2.5	4.675	1.000	PASS
Sliding (kN/m)	12.4	4.9	2.535	1.000	PASS

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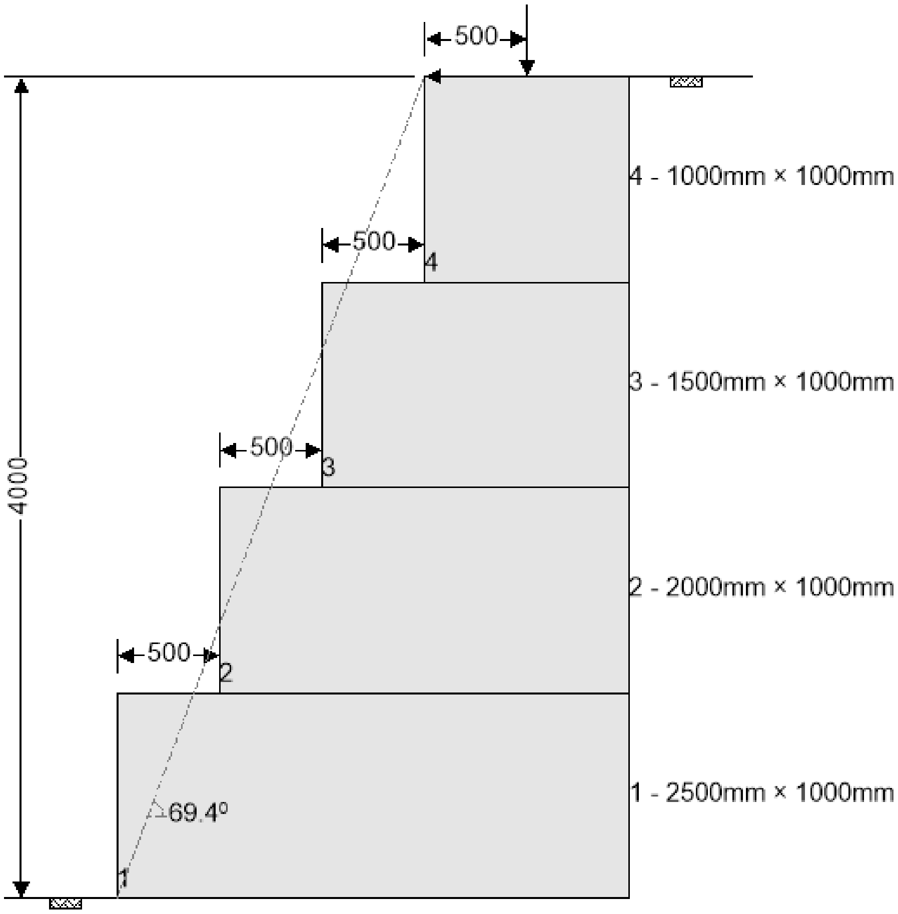

Wall geometry

Width of gabion 1;	w_1 = **2500** mm
Height of gabion 1;	h_1 = **1000** mm
Width of gabion 2;	w_2 = **2000** mm
Height of gabion 2;	h_2 = **1000** mm
Step to front face between courses 1 and 2;	s_2 = **500** mm
Width of gabion 3;	w_3 = **1500** mm
Height of gabion 3;	h_3 = **1000** mm
Step to front face between courses 2 and 3;	s_3 = **500** mm
Width of gabion 4;	w_4 = **1000** mm
Height of gabion 4;	h_4 = **1000** mm
Step to front face between courses 3 and 4;	s_4 = **500** mm
Wall inclination;	ε = **0** deg

Gabion properties

Unit weight of fill;	γ_d = **16.0** kN/m^3
Friction between gabions;	$\delta_{bg.k}$ = **35.0** deg

Loading

Permanent horizontal line load;	$F_{h,G}$ = **0** kN/m
Variable horizontal line load;	$F_{h,Q}$ = **1** kN/m
Vertical height of horizontal load from top gabion;	H_{hl} = **0** mm
Dist of horiz. load from leading edge of top gabion;	D_{hl} = **0** mm
Permanent vertical line load;	$F_{v,G}$ = **5** kN/m
Variable vertical line load;	$F_{v,Q}$ = **2** kN/m

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Dist of vert. load from leading edge of top gabion; D_{vl} = **500** mm

Soil properties

Slope of retained soil; β = **0.0** deg

Characteristic effective shearing resistance angle; $\phi'_{r.k}$ = **30.0** deg

Characteristic saturated density of retained soil; γ_{sr} = **21.0** kN/m^3

Coefficient for wall friction; $k_{membrane}$ = **0.75**

Wall friction angle; $\delta_{r.k}$ = **22.5** deg

Characteristic base friction angle; $\delta_{bb.k}$ = **30.0** deg

Bearing capacity of founding soil; q = **150** kN/m^2

Wall geometry

Horizontal distance to centre of gravity gabion 1; $x_{g1} = w_1 / 2$ = **1250** mm

Vertical distance to centre of gravity gabion 1; $y_{g1} = h_1 / 2$ = **500** mm

Weight of gabion 1; $W_{g1} = \gamma_d \times w_1 \times h_1$ = **40.0** kN/m

Horizontal distance to centre of gravity gabion 2; $x_{g2} = w_2 / 2 + s_2$ = **1500** mm

Vertical distance to centre of gravity gabion 2; $y_{g2} = h_2 / 2 + h_1$ = **1500** mm

Weight of gabion 2; $W_{g2} = \gamma_d \times w_2 \times h_2$ = **32.0** kN/m

Horizontal distance to centre of gravity gabion 3; $x_{g3} = w_3 / 2 + s_2 + s_3$ = **1750** mm

Vertical distance to centre of gravity gabion 3; $y_{g3} = h_3 / 2 + h_1 + h_2$ = **2500** mm

Weight of gabion 3; $W_{g3} = \gamma_d \times w_3 \times h_3$ = **24.0** kN/m

Horizontal distance to centre of gravity gabion 4; $x_{g4} = w_4 / 2 + s_2 + s_3 + s_4$ = **2000** mm

Vertical distance to centre of gravity gabion 4; $y_{g4} = h_4 / 2 + h_1 + h_2 + h_3$ = **3500** mm

Weight of gabion 4; $W_{g4} = \gamma_d \times w_4 \times h_4$ = **16.0** kN/m

Weight of entire gabion; $W_g = W_{g1} + W_{g2} + W_{g3} + W_{g4}$ = **112.0** kN/m

Horiz distance to centre of gravity entire gabion; $x_g = ((W_{g1} \times x_{g1}) + (W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4})) / W_g$ = **1536** mm

Vert distance to centre of gravity entire gabion; $y_g = ((W_{g1} \times y_{g1}) + (W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4})) / W_g$ = **1643** mm

Correcting for wall inclination horiz dist; $X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon)$ = **1536** mm

Vertical change in height due to wall inclination; $H_f = y_{g4} + h_4/2 - ((y_{g4} + h_4/2) \times \cos(\varepsilon) - (x_{g4} + w_4/2) \times \sin(\varepsilon))$ = **0** mm

Design dimensions

Effective angle of rear plane of wall; $\alpha = 90 \text{ deg} + \varepsilon$ = **90.0** deg

Effective face angle; $\theta = \text{Atan}((y_{g4} + (h_4 / 2)) / ((x_{g4} - (w_4 / 2)))) - \varepsilon$ = **69.4** deg

Effective height of wall; $H = (y_{g4} + h_4 / 2) + (w_1 \times \sin(\varepsilon)) - H_f$ = **4000** mm

Height of wall from toe to front edge of top gabion; $H_{incl} = ((y_{g4} + h_4 / 2) \times \cos(\varepsilon) - (x_{g4} - (w_4 / 2)) \times \sin(\varepsilon))$ = **4000**mm

Active pressure using Coulomb theory; $K_a = \sin(\alpha + \phi'_{r.k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.k}) \times (1 + \sqrt{(\sin(\phi'_{r.k} + \delta_{r.k}) \times \sin(\phi'_{r.k} - \beta) / (\sin(\alpha - \delta_{r.k}) \times \sin(\alpha + \beta)))})^2)$ = **0.296**

Active thrust due to soil; $P_{a,soil} = 0.5 \times K_a \times \gamma_{sr} \times H^2$ = **49.8** kN/m

Pressure at base

Horizontal forces

Retained soil; $F_{soil\_h,q} = P_{a,soil} \times \cos(90 - \alpha + \delta_{r.k})$ = **46.0** kN/m

Height of soil thrust resolved vertically; $d_{h,soil} = H / 3 - w_1 \times \sin(\varepsilon)$ = **1333** mm

Line loading; $F_{line\_h,q} = F_{h,Q}$ = **1.0** kN/m

Vertical distance to where load acts; $d_{h,line} = H_{incl} + H_{hl} - D_{hl} \times \tan(\varepsilon)$ = **4000** mm

Vertical forces

Gabion weight; $F_{gabion\_v,q} = W_g$ = **112.0** kN/m

Retained soil; $F_{soil\_v,q} = P_{a,soil} \times \sin(90 - \alpha + \delta_{r.k})$ = **19.0** kN/m

Horizontal dist to where soil thrust acts; $b_{v,soil} = w_1 \times \cos(\varepsilon) - (H / 3) / \tan(\alpha)$ = **2500** mm

Line loading; $F_{line\_v,q} = (F_{v,G} + F_{v,Q})$ = **7.0** kN/m

Horizontal distance to where load acts; $b_{v,line} = H_{incl} / \tan(\theta) + D_{vl} = \mathbf{2000}$ mm

Total horizontal unfactored force; $T_q = F_{soil\_h,q} + F_{line\_h,q} = \mathbf{47.0}$ kN/m

Total vertical unfactored force; $N_q = F_{gabion\_v,q} + F_{soil\_v,q} + F_{line\_v,q} = \mathbf{138.0}$ kN/m

Force normal to base; $N_s = N_q \times \cos(\varepsilon) + T_q \times \sin(\varepsilon) = \mathbf{138.0}$ kN/m

Total unfactored overturning force; $M_{o,q} = F_{soil\_h,q} \times d_{h,soil} + F_{line\_h,q} \times d_{h,line} = \mathbf{65.3}$ kNm/m

Total unfactored restoring force; $M_{R,q} = F_{gabion\_v,q} \times X_g + F_{soil\_v,q} \times b_{v,soil} + F_{line\_v,q} \times b_{v,line} = \mathbf{233.6}$ kNm/m

Eccentricity; $e = w_1 / 2 - (M_{R,q} - M_{o,q}) / N_s = \mathbf{31}$ mm

Reaction acts within middle third of base

Pressure at toe; $\sigma_{toe} = N_s / w_1 \times (1 + (6 \times e / w_1)) = \mathbf{59.3}$ kN/m^2

Pressure at heel; $\sigma_{heel} = N_s / w_1 \times (1 - (6 \times e / w_1)) = \mathbf{51.1}$ kN/m^2

Factor of safety; $FoS_Q = q / \max(\sigma_{toe}, \sigma_{heel}) = \mathbf{2.529}$

Allowable factor of safety; $FoS_{Q\_allow} = \mathbf{1.000}$

PASS - Design FoS for allowable bearing pressure exceeds min allowable pressure to base

Design approach 1

Partial factors on actions - Section A.3.1 - Combination 1

Permanent unfavourable action; $\gamma_G = \mathbf{1.35}$

Permanent favourable action; $\gamma_{G,f} = \mathbf{1.00}$

Variable unfavourable action; $\gamma_Q = \mathbf{1.50}$

Variable favourable action; $\gamma_{Q,f} = \mathbf{0.00}$

Partial factors for soil parameters - Section A.3.2 - Combination 1

Angle of shearing resistance; $\gamma_{\phi'} = \mathbf{1.00}$

Weight density; $\gamma_\gamma = \mathbf{1.00}$

Design soil properties

Design effective shearing resistance angle; $\phi'_{r.d} = \mathrm{Atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'}) = \mathbf{30.0}$ deg

Design saturated density of retained soil; $\gamma_{s.d} = \gamma_{sr} / \gamma_\gamma = \mathbf{21.0}$ kN/m^3

Design wall friction angle; $\delta_{r.d} = \min(\mathrm{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'}), \phi'_{r.d} \times k_{membrane}) = \mathbf{22.5}$ deg

Design base friction angle; $\delta_{bb.d} = \mathrm{Atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'}) = \mathbf{30.0}$ deg

Design friction between gabions; $\delta_{bg.d} = \mathrm{Atan}(\tan(\delta_{bg.k}) / \gamma_{\phi'}) = \mathbf{35.0}$ deg

Active pressure using Coulomb theory; $K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times (1 + \sqrt{}(\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))))^2) = \mathbf{0.296}$

Active thrust due to soil; $P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2 = \mathbf{49.8}$ kN/m

Horizontal forces

Retained soil; $F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d}) = \mathbf{62.1}$ kN/m

Line loading; $F_{line\_h} = F_{h,Q} \times \gamma_Q = \mathbf{1.5}$ kN/m

Vertical forces

Gabion weight; $F_{gabion\_v,f} = \gamma_{G,f} \times W_g = \mathbf{112.0}$ kN/m

Retained soil; $F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d}) = \mathbf{19.0}$ kN/m

Line loading; $F_{line\_v,f} = (F_{v,G} \times \gamma_{G,f} + F_{v,Q} \times \gamma_{Q,f}) = \mathbf{5.0}$ kN/m

Overturning stability - take moments about the toe

Overturning moment; $M_o = F_{soil\_h} \times d_{h,soil} + F_{line\_h} \times d_{h,line} = \mathbf{88.8}$ kNm/m

Restoring moment; $M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{line\_v,f} \times b_{v,line} = \mathbf{229.6}$ kNm/m

Factor of safety; $FoS_M = M_R / M_o = \mathbf{2.586}$

Allowable factor of safety; $FoS_{M\_allow} = \mathbf{1.000}$

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PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force; $T = F_{soil\_h} + F_{line\_h} = \mathbf{63.6}$ kN/m

Total vertical force; $N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{line\_v,f} =$ **136.0** kN/m

Sliding force; $F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) =$ **63.6** kN/m

Sliding resistance; $F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bb.d}) =$ **78.5** kN/m

Factor of safety; $FoS_S = F_R / F_f =$ **1.235**

Allowable factor of safety; $FoS_{S\_allow} =$ **1.000**

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

Check overturning and sliding between courses 1 and 2

Wall geometry

Horizontal distance to centre of gravity gabion 2; $x_{g2} = w_2 / 2 =$ **1000** mm

Vertical distance to centre of gravity gabion 2; $y_{g2} = h_2 / 2 =$ **500** mm

Weight of gabion 2; $W_{g2} = \gamma_d \times w_2 \times h_2 =$ **32.0** kN/m

Horizontal distance to centre of gravity gabion 3; $x_{g3} = w_3 / 2 + s_3 =$ **1250** mm

Vertical distance to centre of gravity gabion 3; $y_{g3} = h_3 / 2 + h_2 =$ **1500** mm

Weight of gabion 3; $W_{g3} = \gamma_d \times w_3 \times h_3 =$ **24.0** kN/m

Horizontal distance to centre of gravity gabion 4; $x_{g4} = w_4 / 2 + s_3 + s_4 =$ **1500** mm

Vertical distance to centre of gravity gabion 4; $y_{g4} = h_4 / 2 + h_2 + h_3 =$ **2500** mm

Weight of gabion 4; $W_{g4} = \gamma_d \times w_4 \times h_4 =$ **16.0** kN/m

Weight of entire gabion; $W_g = W_{g2} + W_{g3} + W_{g4} =$ **72.0** kN/m

Horiz distance to centre of gravity entire gabion; $x_g = ((W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4})) / W_g =$ **1194** mm

Vert distance to centre of gravity entire gabion; $y_g = ((W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4})) / W_g =$ **1278** mm

Correcting for wall inclination horiz dist; $X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) =$ **1194** mm

Vertical change in height due to wall inclination; $H_f = y_{g4} + h_4/2 - ((y_{g4} + h_4/2) \times \cos(\varepsilon) - (x_{g4} + w_4/2) \times \sin(\varepsilon)) =$ **0** mm

Design dimensions

Effective angle of rear plane of wall; $\alpha = 90 \text{ deg} + \varepsilon =$ **90.0** deg

Effective face angle; $\theta = \text{Atan}((y_{g4} + (h_4 / 2)) / ((x_{g4} - (w_4 / 2)))) - \varepsilon =$ **71.6** deg

Effective height of wall; $H = (y_{g4} + h_4 / 2) + (w_2 \times \sin(\varepsilon)) - H_f =$ **3000** mm

Height of wall from toe to front edge of top gabion; $H_{incl} = ((y_{g4} + h_4 / 2) \times \cos(\varepsilon) - (x_{g4} - (w_4 / 2)) \times \sin(\varepsilon)) =$ **3000**mm

Active pressure using Coulomb theory; $K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times (1 + \sqrt{(\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta)))})^2) =$ **0.296**

Active thrust due to soil; $P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2 =$ **28.0** kN/m

Horizontal forces

Retained soil; $F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d}) =$ **34.9** kN/m

Line loading; $F_{line\_h} = F_{h,Q} \times \gamma_Q =$ **1.5** kN/m

Vertical forces

Gabion weight; $F_{gabion\_v,f} = \gamma_{G,f} \times W_g =$ **72.0** kN/m

Retained soil; $F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d}) =$ **10.7** kN/m

Line loading; $F_{line\_v,f} = (F_{v,G} \times \gamma_{G,f} + F_{v,Q} \times \gamma_{Q,f}) =$ **5.0** kN/m

Overturning stability - take moments about the toe

Overturning moment; $M_o = F_{soil\_h} \times d_{h,soil} + F_{line\_h} \times d_{h,line} =$ **39.4** kNm/m

Restoring moment; $M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{line\_v,f} \times b_{v,line} =$ **114.9** kNm/m

Factor of safety; $FoS_M = M_R / M_o =$ **2.915**

Allowable factor of safety; $FoS_{M\_allow} =$ **1.000**

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

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Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force; $T = F_{soil\_h} + F_{line\_h} =$ **36.4** kN/m

Total vertical force; $N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{line\_v,f} =$ **87.7** kN/m

Sliding force; $F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) = \mathbf{36.4}$ kN/m

Sliding resistance; $F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bg.d}) = \mathbf{61.4}$ kN/m

Factor of safety; $FoS_S = F_R / F_f = \mathbf{1.686}$

Allowable factor of safety; $FoS_{S\_allow} = \mathbf{1.000}$

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

Check overturning and sliding between courses 2 and 3

Wall geometry

Horizontal distance to centre of gravity gabion 3; $x_{g3} = w_3 / 2 = \mathbf{750}$ mm

Vertical distance to centre of gravity gabion 3; $y_{g3} = h_3 / 2 = \mathbf{500}$ mm

Weight of gabion 3; $W_{g3} = \gamma_d \times w_3 \times h_3 = \mathbf{24.0}$ kN/m

Horizontal distance to centre of gravity gabion 4; $x_{g4} = w_4 / 2 + s_4 = \mathbf{1000}$ mm

Vertical distance to centre of gravity gabion 4; $y_{g4} = h_4 / 2 + h_3 = \mathbf{1500}$ mm

Weight of gabion 4; $W_{g4} = \gamma_d \times w_4 \times h_4 = \mathbf{16.0}$ kN/m

Weight of entire gabion; $W_g = W_{g3} + W_{g4} = \mathbf{40.0}$ kN/m

Horiz distance to centre of gravity entire gabion; $x_g = ((W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4})) / W_g = \mathbf{850}$ mm

Vert distance to centre of gravity entire gabion; $y_g = ((W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4})) / W_g = \mathbf{900}$ mm

Correcting for wall inclination horiz dist; $X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) = \mathbf{850}$ mm

Vertical change in height due to wall inclination; $H_f = y_{g4} + h_4/2 - ((y_{g4} + h_4/2) \times \cos(\varepsilon) - (x_{g4} + w_4/2) \times \sin(\varepsilon)) = \mathbf{0}$ mm

Design dimensions

Effective angle of rear plane of wall; $\alpha = 90 \text{ deg} + \varepsilon = \mathbf{90.0}$ deg

Effective face angle; $\theta = \text{Atan}((y_{g4} + (h_4 / 2)) / ((x_{g4} - (w_4 / 2)))) - \varepsilon = \mathbf{76.0}$ deg

Effective height of wall; $H = (y_{g4} + h_4 / 2) + (w_3 \times \sin(\varepsilon)) - H_f = \mathbf{2000}$ mm

Height of wall from toe to front edge of top gabion; $H_{incl} = ((y_{g4} + h_4 / 2) \times \cos(\varepsilon) - (x_{g4} - (w_4 / 2)) \times \sin(\varepsilon)) = \mathbf{2000}$mm

Active pressure using Coulomb theory; $K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times (1 + \sqrt{}(\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))))^2) = \mathbf{0.296}$

Active thrust due to soil; $P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2 = \mathbf{12.4}$ kN/m

Horizontal forces

Retained soil; $F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d}) = \mathbf{15.5}$ kN/m

Line loading; $F_{line\_h} = F_{h,Q} \times \gamma_Q = \mathbf{1.5}$ kN/m

Vertical forces

Gabion weight; $F_{gabion\_v,f} = \gamma_{G,f} \times W_g = \mathbf{40.0}$ kN/m

Retained soil; $F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d}) = \mathbf{4.8}$ kN/m

Line loading; $F_{line\_v,f} = (F_{v,G} \times \gamma_{G,f} + F_{v,Q} \times \gamma_{Q,f}) = \mathbf{5.0}$ kN/m

Overturning stability - take moments about the toe

Overturning moment; $M_o = F_{soil\_h} \times d_{h,soil} + F_{line\_h} \times d_{h,line} = \mathbf{13.3}$ kNm/m

Restoring moment; $M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{line\_v,f} \times b_{v,line} = \mathbf{46.1}$ kNm/m

Factor of safety; $FoS_M = M_R / M_o = \mathbf{3.457}$

Allowable factor of safety; $FoS_{M\_allow} = \mathbf{1.000}$

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force; $T = F_{soil\_h} + F_{line\_h} = \mathbf{17.0}$ kN/m

Total vertical force; $N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{line\_v,f} = \mathbf{49.8}$ kN/m

Sliding force; $F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) = \mathbf{17.0}$ kN/m

Sliding resistance; $F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bg.d}) = \mathbf{34.8}$ kN/m

Factor of safety; $FoS_S = F_R / F_f = \mathbf{2.047}$

Allowable factor of safety; $FoS_{S\_allow} = \mathbf{1.000}$

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PASS - Design FOS for sliding exceeds min allowable FOS for sliding

Check overturning and sliding between courses 3 and 4

Wall geometry

Horizontal distance to centre of gravity gabion 4; $x_{g4} = w_4 / 2 = \mathbf{500}$ mm

Vertical distance to centre of gravity gabion 4; $y_{g4} = h_4 / 2 = \mathbf{500}$ mm

Weight of gabion 4; $W_{g4} = \gamma_d \times w_4 \times h_4 = \mathbf{16.0}$ kN/m

Weight of entire gabion; $W_g = W_{g4} = \mathbf{16.0}$ kN/m

Horiz distance to centre of gravity entire gabion; $x_g = ((W_{g4} \times x_{g4})) / W_g = \mathbf{500}$ mm

Vert distance to centre of gravity entire gabion; $y_g = ((W_{g4} \times y_{g4})) / W_g = \mathbf{500}$ mm

Correcting for wall inclination horiz dist; $X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) = \mathbf{500}$ mm

Vertical change in height due to wall inclination; $H_f = y_{g4} + h_4/2 - ((y_{g4} + h_4/2) \times \cos(\varepsilon) - (x_{g4} + w_4/2) \times \sin(\varepsilon)) = \mathbf{0}$ mm

Design dimensions

Effective angle of rear plane of wall; $\alpha = 90\text{ deg} + \varepsilon = \mathbf{90.0}$ deg

Effective face angle; $\theta = 90\text{deg} - \varepsilon = \mathbf{90.0}$ deg

Effective height of wall; $H = (y_{g4} + h_4 / 2) + (w_4 \times \sin(\varepsilon)) - H_f = \mathbf{1000}$ mm

Height of wall from toe to front edge of top gabion; $H_{incl} = ((y_{g4} + h_4 / 2) \times \cos(\varepsilon) - (x_{g4} - (w_4 / 2)) \times \sin(\varepsilon)) = \mathbf{1000}$mm

Active pressure using Coulomb theory; $K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times (1 + \sqrt{(\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta)))})^2) = \mathbf{0.296}$

Active thrust due to soil; $P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2 = \mathbf{3.1}$ kN/m

Horizontal forces

Retained soil; $F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d}) = \mathbf{3.9}$ kN/m

Line loading; $F_{line\_h} = F_{h,Q} \times \gamma_Q = \mathbf{1.5}$ kN/m

Vertical forces

Gabion weight; $F_{gabion\_v,f} = \gamma_{G,f} \times W_g = \mathbf{16.0}$ kN/m

Retained soil; $F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d}) = \mathbf{1.2}$ kN/m

Line loading; $F_{line\_v,f} = (F_{v,G} \times \gamma_{G,f} + F_{v,Q} \times \gamma_{Q,f}) = \mathbf{5.0}$ kN/m

Overturning stability - take moments about the toe

Overturning moment; $M_o = F_{soil\_h} \times d_{h,soil} + F_{line\_h} \times d_{h,line} = \mathbf{2.8}$ kNm/m

Restoring moment; $M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{line\_v,f} \times b_{v,line} = \mathbf{11.7}$ kNm/m

Factor of safety; $FoS_M = M_R / M_o = \mathbf{4.185}$

Allowable factor of safety; $FoS_{M\_allow} = \mathbf{1.000}$

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force; $T = F_{soil\_h} + F_{line\_h} = \mathbf{5.4}$ kN/m

Total vertical force; $N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{line\_v,f} = \mathbf{22.2}$ kN/m

Sliding force; $F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) = \mathbf{5.4}$ kN/m

Sliding resistance; $F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bg.d}) = \mathbf{15.5}$ kN/m

Factor of safety; $FoS_S = F_R / F_f = \mathbf{2.888}$

Allowable factor of safety; $FoS_{S\_allow} = \mathbf{1.000}$

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

Design approach 1

Partial factors on actions - Section A.3.1 - Combination 2

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Permanent unfavourable action; $\gamma_G = \mathbf{1.00}$

Permanent favourable action; $\gamma_{G,f} = \mathbf{1.00}$

Variable unfavourable action; $\gamma_Q = \mathbf{1.30}$

Variable favourable action; $\gamma_{Q,f} = \mathbf{0.00}$

Partial factors for soil parameters - Section A.3.2 - Combination 2

Angle of shearing resistance; $\gamma_{\phi'}$ = **1.25**

Weight density; γ_{γ} = **1.00**

Design soil properties

Design effective shearing resistance angle; $\phi'_{r.d} = \text{Atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'}) = \mathbf{24.8}$ deg

Design saturated density of retained soil; $\gamma_{s.d} = \gamma_{sr} / \gamma_{\gamma} = \mathbf{21.0}$ kN/m^3

Design wall friction angle; $\delta_{r.d} = \min(\text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'}), \phi'_{r.d} \times k_{membrane}) = \mathbf{18.3}$ deg

Design base friction angle; $\delta_{bb.d} = \text{Atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'}) = \mathbf{24.8}$ deg

Design friction between gabions; $\delta_{bg.d} = \text{Atan}(\tan(\delta_{bg.k}) / \gamma_{\phi'}) = \mathbf{29.3}$ deg

Wall geometry

Horizontal distance to centre of gravity gabion 1; $x_{g1} = w_1 / 2 = \mathbf{1250}$ mm

Vertical distance to centre of gravity gabion 1; $y_{g1} = h_1 / 2 = \mathbf{500}$ mm

Weight of gabion 1; $W_{g1} = \gamma_d \times w_1 \times h_1 = \mathbf{40.0}$ kN/m

Horizontal distance to centre of gravity gabion 2; $x_{g2} = w_2 / 2 + s_2 = \mathbf{1500}$ mm

Vertical distance to centre of gravity gabion 2; $y_{g2} = h_2 / 2 + h_1 = \mathbf{1500}$ mm

Weight of gabion 2; $W_{g2} = \gamma_d \times w_2 \times h_2 = \mathbf{32.0}$ kN/m

Horizontal distance to centre of gravity gabion 3; $x_{g3} = w_3 / 2 + s_2 + s_3 = \mathbf{1750}$ mm

Vertical distance to centre of gravity gabion 3; $y_{g3} = h_3 / 2 + h_1 + h_2 = \mathbf{2500}$ mm

Weight of gabion 3; $W_{g3} = \gamma_d \times w_3 \times h_3 = \mathbf{24.0}$ kN/m

Horizontal distance to centre of gravity gabion 4; $x_{g4} = w_4 / 2 + s_2 + s_3 + s_4 = \mathbf{2000}$ mm

Vertical distance to centre of gravity gabion 4; $y_{g4} = h_4 / 2 + h_1 + h_2 + h_3 = \mathbf{3500}$ mm

Weight of gabion 4; $W_{g4} = \gamma_d \times w_4 \times h_4 = \mathbf{16.0}$ kN/m

Weight of entire gabion; $W_g = W_{g1} + W_{g2} + W_{g3} + W_{g4} = \mathbf{112.0}$ kN/m

Horiz distance to centre of gravity entire gabion; $x_g = ((W_{g1} \times x_{g1}) + (W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4})) / W_g = \mathbf{1536}$ mm

Vert distance to centre of gravity entire gabion; $y_g = ((W_{g1} \times y_{g1}) + (W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4})) / W_g = \mathbf{1643}$ mm

Correcting for wall inclination horiz dist; $X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) = \mathbf{1536}$ mm

Vertical change in height due to wall inclination; $H_f = y_{g4} + h_4/2 - ((y_{g4} + h_4/2) \times \cos(\varepsilon) - (x_{g4} + w_4/2) \times \sin(\varepsilon)) = \mathbf{0}$ mm

Design dimensions

Effective angle of rear plane of wall; $\alpha = 90 \text{ deg} + \varepsilon = \mathbf{90.0}$ deg

Effective face angle; $\theta = \text{Atan}((y_{g4} + (h_4 / 2)) / ((x_{g4} - (w_4 / 2)))) - \varepsilon = \mathbf{69.4}$ deg

Effective height of wall; $H = (y_{g4} + h_4 / 2) + (w_1 \times \sin(\varepsilon)) - H_f = \mathbf{4000}$ mm

Height of wall from toe to front edge of top gabion; $H_{incl} = ((y_{g4} + h_4 / 2) \times \cos(\varepsilon) - (x_{g4} - (w_4 / 2)) \times \sin(\varepsilon)) = \mathbf{4000}$mm

Active pressure using Coulomb theory; $K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times (1 + \sqrt{(\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta)))})^2) = \mathbf{0.362}$

Active thrust due to soil; $P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2 = \mathbf{60.8}$ kN/m

Horizontal forces

Retained soil; $F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d}) = \mathbf{57.7}$ kN/m

Line loading; $F_{line\_h} = F_{h,Q} \times \gamma_Q = \mathbf{1.3}$ kN/m

Vertical forces

Gabion weight; $F_{gabion\_v,f} = \gamma_{G,f} \times W_g = \mathbf{112.0}$ kN/m

Retained soil; $F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d}) = \mathbf{19.1}$ kN/m

Line loading; $F_{line\_v,f} = (F_{v,G} \times \gamma_{G,f} + F_{v,Q} \times \gamma_{Q,f}) = \mathbf{5.0}$ kN/m

Overturning stability - take moments about the toe

Overturning moment; $M_o = F_{soil\_h} \times d_{h,soil} + F_{line\_h} \times d_{h,line} = \mathbf{82.1}$ kNm/m

Restoring moment; $M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{line\_v,f} \times b_{v,line} = \mathbf{229.8}$ kNm/m

Factor of safety; $FoS_M = M_R / M_o = \mathbf{2.799}$

Allowable factor of safety; $FoS_{M\_allow} = \mathbf{1.000}$

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force; $T = F_{soil\_h} + F_{line\_h} = \mathbf{59.0}$ kN/m

Total vertical force; $N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{line\_v,f} = \mathbf{136.1}$ kN/m

Sliding force; $F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) = \mathbf{59.0}$ kN/m

Sliding resistance; $F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bb.d}) = \mathbf{62.9}$ kN/m

Factor of safety; $FoS_S = F_R / F_f = \mathbf{1.066}$

Allowable factor of safety; $FoS_{S\_allow} = \mathbf{1.000}$

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

<u>Check overturning and sliding between courses 1 and 2</u>

Wall geometry

Horizontal distance to centre of gravity gabion 2; $x_{g2} = w_2 / 2 = \mathbf{1000}$ mm

Vertical distance to centre of gravity gabion 2; $y_{g2} = h_2 / 2 = \mathbf{500}$ mm

Weight of gabion 2; $W_{g2} = \gamma_d \times w_2 \times h_2 = \mathbf{32.0}$ kN/m

Horizontal distance to centre of gravity gabion 3; $x_{g3} = w_3 / 2 + s_3 = \mathbf{1250}$ mm

Vertical distance to centre of gravity gabion 3; $y_{g3} = h_3 / 2 + h_2 = \mathbf{1500}$ mm

Weight of gabion 3; $W_{g3} = \gamma_d \times w_3 \times h_3 = \mathbf{24.0}$ kN/m

Horizontal distance to centre of gravity gabion 4; $x_{g4} = w_4 / 2 + s_3 + s_4 = \mathbf{1500}$ mm

Vertical distance to centre of gravity gabion 4; $y_{g4} = h_4 / 2 + h_2 + h_3 = \mathbf{2500}$ mm

Weight of gabion 4; $W_{g4} = \gamma_d \times w_4 \times h_4 = \mathbf{16.0}$ kN/m

Weight of entire gabion; $W_g = W_{g2} + W_{g3} + W_{g4} = \mathbf{72.0}$ kN/m

Horiz distance to centre of gravity entire gabion; $x_g = ((W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4})) / W_g = \mathbf{1194}$ mm

Vert distance to centre of gravity entire gabion; $y_g = ((W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4})) / W_g = \mathbf{1278}$ mm

Correcting for wall inclination horiz dist; $X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) = \mathbf{1194}$ mm

Vertical change in height due to wall inclination; $H_f = y_{g4} + h_4/2 - ((y_{g4} + h_4/2) \times \cos(\varepsilon) - (x_{g4} + w_4/2) \times \sin(\varepsilon)) = \mathbf{0}$ mm

Design dimensions

Effective angle of rear plane of wall; $\alpha = 90 \text{ deg} + \varepsilon = \mathbf{90.0}$ deg

Effective face angle; $\theta = \text{Atan}((y_{g4} + (h_4 / 2)) / ((x_{g4} - (w_4 / 2)))) - \varepsilon = \mathbf{71.6}$ deg

Effective height of wall; $H = (y_{g4} + h_4 / 2) + (w_2 \times \sin(\varepsilon)) - H_f = \mathbf{3000}$ mm

Height of wall from toe to front edge of top gabion; $H_{incl} = ((y_{g4} + h_4 / 2) \times \cos(\varepsilon) - (x_{g4} - (w_4 / 2)) \times \sin(\varepsilon)) = \mathbf{3000}$mm

Active pressure using Coulomb theory; $K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times (1 + \surd(\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))))^2) = \mathbf{0.362}$

Active thrust due to soil; $P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2 = \mathbf{34.2}$ kN/m

Horizontal forces

Retained soil; $F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d}) = \mathbf{32.4}$ kN/m

Line loading; $F_{line\_h} = F_{h,Q} \times \gamma_Q = \mathbf{1.3}$ kN/m

Vertical forces

Gabion weight; $F_{gabion\_v,f} = \gamma_{G,f} \times W_g = \mathbf{72.0}$ kN/m

Retained soil; $F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d}) = \mathbf{10.7}$ kN/m

Line loading; $F_{line\_v,f} = (F_{v,G} \times \gamma_{G,f} + F_{v,Q} \times \gamma_{Q,f}) = \mathbf{5.0}$ kN/m

Overturning stability - take moments about the toe

Overturning moment; $M_o = F_{soil\_h} \times d_{h,soil} + F_{line\_h} \times d_{h,line} = \mathbf{36.3}$ kNm/m

Restoring moment; $M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{line\_v,f} \times b_{v,line} = \mathbf{115.0}$ kNm/m

Factor of safety; $FoS_M = M_R / M_o = \mathbf{3.165}$

Allowable factor of safety; $FoS_{M\_allow} = \mathbf{1.000}$

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force; $T = F_{soil\_h} + F_{line\_h} = \mathbf{33.7}$ kN/m

Total vertical force; $N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{line\_v,f} = \mathbf{87.7}$ kN/m

Sliding force; $F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) = \mathbf{33.7}$ kN/m

Sliding resistance; $F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bg.d}) = \mathbf{49.2}$ kN/m

Factor of safety; $FoS_S = F_R / F_f = \mathbf{1.457}$

Allowable factor of safety; $FoS_{S\_allow} = \mathbf{1.000}$

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

<u>Check overturning and sliding between courses 2 and 3</u>

Wall geometry

Horizontal distance to centre of gravity gabion 3; $x_{g3} = w_3 / 2 = \mathbf{750}$ mm

Vertical distance to centre of gravity gabion 3; $y_{g3} = h_3 / 2 = \mathbf{500}$ mm

Weight of gabion 3; $W_{g3} = \gamma_d \times w_3 \times h_3 = \mathbf{24.0}$ kN/m

Horizontal distance to centre of gravity gabion 4; $x_{g4} = w_4 / 2 + s_4 = \mathbf{1000}$ mm

Vertical distance to centre of gravity gabion 4; $y_{g4} = h_4 / 2 + h_3 = \mathbf{1500}$ mm

Weight of gabion 4; $W_{g4} = \gamma_d \times w_4 \times h_4 = \mathbf{16.0}$ kN/m

Weight of entire gabion; $W_g = W_{g3} + W_{g4} = \mathbf{40.0}$ kN/m

Horiz distance to centre of gravity entire gabion; $x_g = ((W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4})) / W_g = \mathbf{850}$ mm

Vert distance to centre of gravity entire gabion; $y_g = ((W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4})) / W_g = \mathbf{900}$ mm

Correcting for wall inclination horiz dist; $X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) = \mathbf{850}$ mm

Vertical change in height due to wall inclination; $H_f = y_{g4} + h_4/2 - ((y_{g4} + h_4/2) \times \cos(\varepsilon) - (x_{g4} + w_4/2) \times \sin(\varepsilon)) = \mathbf{0}$ mm

Design dimensions

Effective angle of rear plane of wall; $\alpha = 90 \text{ deg} + \varepsilon = \mathbf{90.0}$ deg

Effective face angle; $\theta = \text{Atan}((y_{g4} + (h_4 / 2)) / ((x_{g4} - (w_4 / 2)))) - \varepsilon = \mathbf{76.0}$ deg

Effective height of wall; $H = (y_{g4} + h_4 / 2) + (w_3 \times \sin(\varepsilon)) - H_f = \mathbf{2000}$ mm

Height of wall from toe to front edge of top gabion; $H_{incl} = ((y_{g4} + h_4 / 2) \times \cos(\varepsilon) - (x_{g4} - (w_4 / 2)) \times \sin(\varepsilon)) = \mathbf{2000}$mm

Active pressure using Coulomb theory; $K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times (1 + \sqrt{(\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta)))})^2) = \mathbf{0.362}$

Active thrust due to soil; $P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2 = \mathbf{15.2}$ kN/m

Horizontal forces

Retained soil; $F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d}) = \mathbf{14.4}$ kN/m

Line loading; $F_{line\_h} = F_{h,Q} \times \gamma_Q = \mathbf{1.3}$ kN/m

Vertical forces

Gabion weight; $F_{gabion\_v,f} = \gamma_{G,f} \times W_g = \mathbf{40.0}$ kN/m

Retained soil; $F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d}) = \mathbf{4.8}$ kN/m

Line loading; $F_{line\_v,f} = (F_{v,G} \times \gamma_{G,f} + F_{v,Q} \times \gamma_{Q,f}) = \mathbf{5.0}$ kN/m

Overturning stability - take moments about the toe

Overturning moment; $M_o = F_{soil\_h} \times d_{h,soil} + F_{line\_h} \times d_{h,line} = \mathbf{12.2}$ kNm/m

Restoring moment; $M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{line\_v,f} \times b_{v,line} = \mathbf{46.2}$ kNm/m

Factor of safety; $FoS_M = M_R / M_o = \mathbf{3.781}$

Allowable factor of safety; $FoS_{M\_allow} = \mathbf{1.000}$

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force; $T = F_{soil\_h} + F_{line\_h} = \mathbf{15.7}$ kN/m

Total vertical force; $N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{line\_v,f} = \mathbf{49.8}$ kN/m

Sliding force; $F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) = \mathbf{15.7}$ kN/m

Sliding resistance; $F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bg.d}) = \mathbf{27.9}$ kN/m

Factor of safety; $FoS_S = F_R / F_f = \mathbf{1.774}$

Allowable factor of safety; $FoS_{S\_allow} = \mathbf{1.000}$

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

<u>Check overturning and sliding between courses 3 and 4</u>

Wall geometry

Horizontal distance to centre of gravity gabion 4; $x_{g4} = w_4 / 2 = \mathbf{500}$ mm

Vertical distance to centre of gravity gabion 4; $y_{g4} = h_4 / 2 = \mathbf{500}$ mm

Weight of gabion 4; $W_{g4} = \gamma_d \times w_4 \times h_4 = \mathbf{16.0}$ kN/m

Weight of entire gabion; $W_g = W_{g4} = \mathbf{16.0}$ kN/m

Horiz distance to centre of gravity entire gabion; $x_g = ((W_{g4} \times x_{g4})) / W_g = \mathbf{500}$ mm

Vert distance to centre of gravity entire gabion; $y_g = ((W_{g4} \times y_{g4})) / W_g = \mathbf{500}$ mm

Correcting for wall inclination horiz dist; $X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) = \mathbf{500}$ mm

Vertical change in height due to wall inclination; $H_f = y_{g4} + h_4/2 - ((y_{g4} + h_4/2) \times \cos(\varepsilon) - (x_{g4} + w_4/2) \times \sin(\varepsilon)) = \mathbf{0}$ mm

Design dimensions

Effective angle of rear plane of wall; $\alpha = 90 \text{ deg} + \varepsilon = \mathbf{90.0}$ deg

Effective face angle; $\theta = 90\text{deg} - \varepsilon = \mathbf{90.0}$ deg

Effective height of wall; $H = (y_{g4} + h_4 / 2) + (w_4 \times \sin(\varepsilon)) - H_f = \mathbf{1000}$ mm

Height of wall from toe to front edge of top gabion; $H_{incl} = ((y_{g4} + h_4 / 2) \times \cos(\varepsilon) - (x_{g4} - (w_4 / 2)) \times \sin(\varepsilon)) = \mathbf{1000}$mm

Active pressure using Coulomb theory; $K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times (1 + \sqrt{(\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta)))})^2) = \mathbf{0.362}$

Active thrust due to soil; $P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2 = \mathbf{3.8}$ kN/m

Horizontal forces

Retained soil; $F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d}) = \mathbf{3.6}$ kN/m

Line loading; $F_{line\_h} = F_{h,Q} \times \gamma_Q = \mathbf{1.3}$ kN/m

Vertical forces

Gabion weight; $F_{gabion\_v,f} = \gamma_{G,f} \times W_g = \mathbf{16.0}$ kN/m

Retained soil; $F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d}) = \mathbf{1.2}$ kN/m

Line loading; $F_{line\_v,f} = (F_{v,G} \times \gamma_{G,f} + F_{v,Q} \times \gamma_{Q,f}) = \mathbf{5.0}$ kN/m

Overturning stability - take moments about the toe

Overturning moment; $M_o = F_{soil\_h} \times d_{h,soil} + F_{line\_h} \times d_{h,line} = \mathbf{2.5}$ kNm/m

Restoring moment; $M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{line\_v,f} \times b_{v,line} = \mathbf{11.7}$ kNm/m

Factor of safety; $FoS_M = M_R / M_o = \mathbf{4.675}$

Allowable factor of safety; $FoS_{M\_allow} = \mathbf{1.000}$

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force; $T = F_{soil\_h} + F_{line\_h} = \mathbf{4.9}$ kN/m

Total vertical force; $N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{line\_v,f} = \mathbf{22.2}$ kN/m

Sliding force; $F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) = \mathbf{4.9}$ kN/m

Sliding resistance; $F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bg.d}) = \mathbf{12.4}$ kN/m

Factor of safety; $FoS_S = F_R / F_f = \mathbf{2.535}$

Allowable factor of safety; $FoS_{S\_allow} = \mathbf{1.000}$

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

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GABION RETAINING WALL ANLYSIS & DESIGN

In accordance with EN 1997-1:2004 - Code of Practice for Geotechnical design and the recommended values

Design summary

Combination 1

Action	Resistance	Force	FoS	Allowable FoS	Status
Overturning, sliding and bearing at base level					
Overturning (kNm/m)	401.8	169.2	2.375	1.000	PASS
Sliding (kN/m)	112.4	98.5	1.142	1.000	PASS
Bearing (kN/m^2)	150.0	74.3	2.018	1.000	PASS
Eccentricity (mm)	Reaction acts within the middle third of base				PASS
Overturning and sliding between courses 1 and 2					
Overturning (kNm/m)	229.6	88.8	2.586	1.000	PASS
Sliding (kN/m)	95.3	63.6	1.498	1.000	PASS
Overturning and sliding between courses 2 and 3					
Overturning (kNm/m)	114.9	39.4	2.915	1.000	PASS
Sliding (kN/m)	61.4	36.4	1.686	1.000	PASS
Overturning and sliding between courses 3 and 4					
Overturning (kNm/m)	46.1	13.3	3.457	1.000	PASS
Sliding (kN/m)	34.8	17.0	2.047	1.000	PASS
Overturning and sliding between courses 4 and 5					
Overturning (kNm/m)	11.7	2.8	4.185	1.000	PASS
Sliding (kN/m)	15.5	5.4	2.888	1.000	PASS

Combination 2

Action	Resistance	Force	FoS	Allowable FoS	Status
Overturning, sliding and bearing at base level					
Overturning (kNm/m)	402.1	156.7	2.566	1.000	PASS
Sliding (kN/m)	90.0	91.4	0.985	1.000	FAIL
Bearing (kN/m^2)	150.0	74.3	2.018	1.000	PASS
Eccentricity (mm)	Reaction acts within the middle third of base				PASS
Overturning and sliding between courses 1 and 2					
Overturning (kNm/m)	229.8	82.1	2.799	1.000	PASS
Sliding (kN/m)	76.2	59.0	1.293	1.000	PASS
Overturning and sliding between courses 2 and 3					
Overturning (kNm/m)	115.0	36.3	3.165	1.000	PASS
Sliding (kN/m)	49.2	33.7	1.457	1.000	PASS
Overturning and sliding between courses 3 and 4					
Overturning (kNm/m)	46.2	12.2	3.781	1.000	PASS
Sliding (kN/m)	27.9	15.7	1.774	1.000	PASS
Overturning and sliding between courses 4 and 5					
Overturning (kNm/m)	11.7	2.5	4.675	1.000	PASS
Sliding (kN/m)	12.4	4.9	2.535	1.000	PASS

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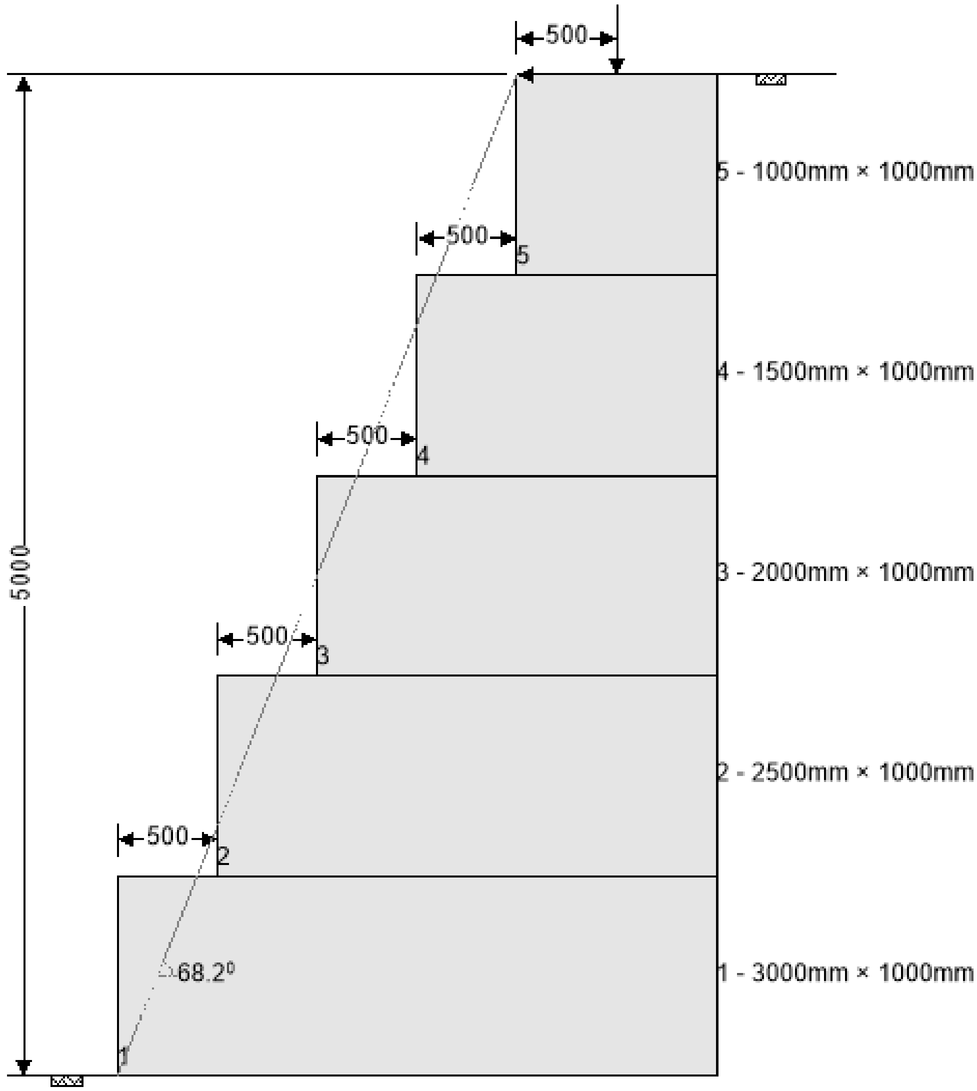

Wall geometry

Width of gabion 1;	w_1 = **3000** mm
Height of gabion 1;	h_1 = **1000** mm
Width of gabion 2;	w_2 = **2500** mm
Height of gabion 2;	h_2 = **1000** mm
Step to front face between courses 1 and 2;	s_2 = **500** mm
Width of gabion 3;	w_3 = **2000** mm
Height of gabion 3;	h_3 = **1000** mm
Step to front face between courses 2 and 3;	s_3 = **500** mm
Width of gabion 4;	w_4 = **1500** mm
Height of gabion 4;	h_4 = **1000** mm
Step to front face between courses 3 and 4;	s_4 = **500** mm
Width of gabion 5;	w_5 = **1000** mm
Height of gabion 5;	h_5 = **1000** mm
Step to front face between courses 4 and 5;	s_5 = **500** mm
Wall inclination;	ε = **0** deg

Gabion properties

Unit weight of fill; γ_d = **16.0** kN/m^3

Friction between gabions; $\delta_{bg.k}$ = **35.0** deg

Loading

Permanent horizontal line load; $F_{h,G}$ = **0** kN/m

Variable horizontal line load; $F_{h,Q}$ = **1** kN/m

Vertical height of horizontal load from top gabion; H_{hl} = **0** mm

Dist of horiz. load from leading edge of top gabion; D_{hl} = **0** mm

Permanent vertical line load; $F_{v,G}$ = **5** kN/m

Variable vertical line load; $F_{v,Q}$ = **2** kN/m

Dist of vert. load from leading edge of top gabion; D_{vl} = **500** mm

Soil properties

Slope of retained soil; β = **0.0** deg

Characteristic effective shearing resistance angle; $\phi'_{r.k}$ = **30.0** deg

Characteristic saturated density of retained soil; γ_{sr} = **21.0** kN/m^3

Coefficient for wall friction; $k_{membrane}$ = **0.75**

Wall friction angle; $\delta_{r.k}$ = **22.5** deg

Characteristic base friction angle; $\delta_{bb.k}$ = **30.0** deg

Bearing capacity of founding soil; q = **150** kN/m^2

Wall geometry

Horizontal distance to centre of gravity gabion 1; $x_{g1} = w_1 / 2$ = **1500** mm

Vertical distance to centre of gravity gabion 1; $y_{g1} = h_1 / 2$ = **500** mm

Weight of gabion 1; $W_{g1} = \gamma_d \times w_1 \times h_1$ = **48.0** kN/m

Horizontal distance to centre of gravity gabion 2; $x_{g2} = w_2 / 2 + s_2$ = **1750** mm

Vertical distance to centre of gravity gabion 2; $y_{g2} = h_2 / 2 + h_1$ = **1500** mm

Weight of gabion 2; $W_{g2} = \gamma_d \times w_2 \times h_2$ = **40.0** kN/m

Horizontal distance to centre of gravity gabion 3; $x_{g3} = w_3 / 2 + s_2 + s_3$ = **2000** mm

Vertical distance to centre of gravity gabion 3; $y_{g3} = h_3 / 2 + h_1 + h_2$ = **2500** mm

Weight of gabion 3; $W_{g3} = \gamma_d \times w_3 \times h_3$ = **32.0** kN/m

Horizontal distance to centre of gravity gabion 4; $x_{g4} = w_4 / 2 + s_2 + s_3 + s_4$ = **2250** mm

Vertical distance to centre of gravity gabion 4; $y_{g4} = h_4 / 2 + h_1 + h_2 + h_3$ = **3500** mm

Weight of gabion 4; $W_{g4} = \gamma_d \times w_4 \times h_4$ = **24.0** kN/m

Horizontal distance to centre of gravity gabion 5; $x_{g5} = w_5 / 2 + s_2 + s_3 + s_4 + s_5$ = **2500** mm

Vertical distance to centre of gravity gabion 5; $y_{g5} = h_5 / 2 + h_1 + h_2 + h_3 + h_4$ = **4500** mm

Weight of gabion 5; $W_{g5} = \gamma_d \times w_5 \times h_5$ = **16.0** kN/m

Weight of entire gabion; $W_g = W_{g1} + W_{g2} + W_{g3} + W_{g4} + W_{g5}$ = **160.0** kN/m

Horiz distance to centre of gravity entire gabion; $x_g = ((W_{g1} \times x_{g1}) + (W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4}) + (W_{g5} \times x_{g5})) / W_g$ = **1875** mm

Vert distance to centre of gravity entire gabion; $y_g = ((W_{g1} \times y_{g1}) + (W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4}) + (W_{g5} \times y_{g5})) / W_g$ = **2000** mm

Correcting for wall inclination horiz dist; $X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon)$ = **1875** mm

Vertical change in height due to wall inclination; $H_f = y_{g5} + h_5/2 - ((y_{g5} + h_5/2) \times \cos(\varepsilon) - (x_{g5} + w_5/2) \times \sin(\varepsilon))$ = **0** mm

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Design dimensions

Effective angle of rear plane of wall; $\alpha = 90 \text{ deg} + \varepsilon$ = **90.0** deg

Effective face angle; $\theta = \text{Atan}((y_{g5} + (h_5 / 2)) / ((x_{g5} - (w_5 / 2)))) - \varepsilon$ = **68.2** deg

Effective height of wall; $H = (y_{g5} + h_5 / 2) + (w_1 \times \sin(\varepsilon)) - H_f =$ **5000** mm

Height of wall from toe to front edge of top gabion; $H_{incl} = ((y_{g5} + h_5 / 2) \times \cos(\varepsilon) - (x_{g5} - (w_5 / 2)) \times \sin(\varepsilon)) =$ **5000**mm

Active pressure using Coulomb theory; $K_a = \sin(\alpha + \phi'_{r.k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.k}) \times (1 + \sqrt{}(\sin(\phi'_{r.k} + \delta_{r.k}) \times \sin(\phi'_{r.k} - \beta) / (\sin(\alpha - \delta_{r.k}) \times \sin(\alpha + \beta))))^2) =$ **0.296**

Active thrust due to soil; $P_{a,soil} = 0.5 \times K_a \times \gamma_{sr} \times H^2 =$ **77.8** kN/m

Pressure at base

Horizontal forces

Retained soil; $F_{soil\_h,q} = P_{a,soil} \times \cos(90 - \alpha + \delta_{r.k}) =$ **71.9** kN/m

Height of soil thrust resolved vertically; $d_{h,soil} = H / 3 - w_1 \times \sin(\varepsilon) =$ **1667** mm

Line loading; $F_{line\_h,q} = F_{h,Q} =$ **1.0** kN/m

Vertical distance to where load acts; $d_{h,line} = H_{incl} + H_{hl} - D_{hl} \times \tan(\varepsilon) =$ **5000** mm

Vertical forces

Gabion weight; $F_{gabion\_v,q} = W_g =$ **160.0** kN/m

Retained soil; $F_{soil\_v,q} = P_{a,soil} \times \sin(90 - \alpha + \delta_{r.k}) =$ **29.8** kN/m

Horizontal dist to where soil thrust acts; $b_{v,soil} = w_1 \times \cos(\varepsilon) - (H / 3) / \tan(\alpha) =$ **3000** mm

Line loading; $F_{line\_v,q} = (F_{v,G} + F_{v,Q}) =$ **7.0** kN/m

Horizontal distance to where load acts; $b_{v,line} = H_{incl} / \tan(\theta) + D_{vl} =$ **2500** mm

Total horizontal unfactored force; $T_q = F_{soil\_h,q} + F_{line\_h,q} =$ **72.9** kN/m

Total vertical unfactored force; $N_q = F_{gabion\_v,q} + F_{soil\_v,q} + F_{line\_v,q} =$ **196.8** kN/m

Force normal to base; $N_s = N_q \times \cos(\varepsilon) + T_q \times \sin(\varepsilon) =$ **196.8** kN/m

Total unfactored overturning force; $M_{o,q} = F_{soil\_h,q} \times d_{h,soil} + F_{line\_h,q} \times d_{h,line} =$ **124.8** kNm/m

Total unfactored restoring force; $M_{R,q} = F_{gabion\_v,q} \times X_g + F_{soil\_v,q} \times b_{v,soil} + F_{line\_v,q} \times b_{v,line} =$ **406.8** kNm/m

Eccentricity; $e = w_1 / 2 - (M_{R,q} - M_{o,q}) / N_s =$ **67** mm

Reaction acts within middle third of base

Pressure at toe; $\sigma_{toe} = N_s / w_1 \times (1 + (6 \times e / w_1)) =$ **74.3** kN/m^2

Pressure at heel; $\sigma_{heel} = N_s / w_1 \times (1 - (6 \times e / w_1)) =$ **56.8** kN/m^2

Factor of safety; $FoS_Q = q / \max(\sigma_{toe}, \sigma_{heel}) =$ **2.018**

Allowable factor of safety; $FoS_{Q\_allow} =$ **1.000**

PASS - Design FoS for allowable bearing pressure exceeds min allowable pressure to base

Design approach 1

Partial factors on actions - Section A.3.1 - Combination 1

Permanent unfavourable action; $\gamma_G =$ **1.35**

Permanent favourable action; $\gamma_{G,f} =$ **1.00**

Variable unfavourable action; $\gamma_Q =$ **1.50**

Variable favourable action; $\gamma_{Q,f} =$ **0.00**

Partial factors for soil parameters - Section A.3.2 - Combination 1

Angle of shearing resistance; $\gamma_{\phi'} =$ **1.00**

Weight density; $\gamma_\gamma =$ **1.00**

Design soil properties

Design effective shearing resistance angle; $\phi'_{r.d} = \text{Atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'}) =$ **30.0** deg

Design saturated density of retained soil; $\gamma_{s.d} = \gamma_{sr} / \gamma_\gamma =$ **21.0** kN/m^3

Design wall friction angle; $\delta_{r.d} = \min(\text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'}), \phi'_{r.d} \times k_{membrane}) =$ **22.5** deg

Design base friction angle; $\delta_{bb.d} = \text{Atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'}) =$ **30.0** deg

Design friction between gabions; $\delta_{bg.d} = \text{Atan}(\tan(\delta_{bg.k}) / \gamma_{\phi'}) =$ **35.0** deg

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Active pressure using Coulomb theory; $K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times (1 + \sqrt{}(\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))))^2) = \mathbf{0.296}$

Active thrust due to soil; $P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2 = \mathbf{77.8}$ kN/m

Horizontal forces

Retained soil; $F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d}) = \mathbf{97.0}$ kN/m

Line loading; $F_{line\_h} = F_{h,Q} \times \gamma_Q = \mathbf{1.5}$ kN/m

Vertical forces

Gabion weight; $F_{gabion\_v,f} = \gamma_{G,f} \times W_g = \mathbf{160.0}$ kN/m

Retained soil; $F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d}) = \mathbf{29.8}$ kN/m

Line loading; $F_{line\_v,f} = (F_{v,G} \times \gamma_{G,f} + F_{v,Q} \times \gamma_{Q,f}) = \mathbf{5.0}$ kN/m

Overturning stability - take moments about the toe

Overturning moment; $M_o = F_{soil\_h} \times d_{h,soil} + F_{line\_h} \times d_{h,line} = \mathbf{169.2}$ kNm/m

Restoring moment; $M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{line\_v,f} \times b_{v,line} = \mathbf{401.8}$ kNm/m

Factor of safety; $FoS_M = M_R / M_o = \mathbf{2.375}$

Allowable factor of safety; $FoS_{M\_allow} = \mathbf{1.000}$

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force; $T = F_{soil\_h} + F_{line\_h} = \mathbf{98.5}$ kN/m

Total vertical force; $N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{line\_v,f} = \mathbf{194.8}$ kN/m

Sliding force; $F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) = \mathbf{98.5}$ kN/m

Sliding resistance; $F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bb.d}) = \mathbf{112.4}$ kN/m

Factor of safety; $FoS_S = F_R / F_f = \mathbf{1.142}$

Allowable factor of safety; $FoS_{S\_allow} = \mathbf{1.000}$

FAIL - Min allowable FOS for sliding exceeds design FOS for sliding

Check overturning and sliding between courses 1 and 2

Wall geometry

Horizontal distance to centre of gravity gabion 2; $x_{g2} = w_2 / 2 = \mathbf{1250}$ mm

Vertical distance to centre of gravity gabion 2; $y_{g2} = h_2 / 2 = \mathbf{500}$ mm

Weight of gabion 2; $W_{g2} = \gamma_d \times w_2 \times h_2 = \mathbf{40.0}$ kN/m

Horizontal distance to centre of gravity gabion 3; $x_{g3} = w_3 / 2 + s_3 = \mathbf{1500}$ mm

Vertical distance to centre of gravity gabion 3; $y_{g3} = h_3 / 2 + h_2 = \mathbf{1500}$ mm

Weight of gabion 3; $W_{g3} = \gamma_d \times w_3 \times h_3 = \mathbf{32.0}$ kN/m

Horizontal distance to centre of gravity gabion 4; $x_{g4} = w_4 / 2 + s_3 + s_4 = \mathbf{1750}$ mm

Vertical distance to centre of gravity gabion 4; $y_{g4} = h_4 / 2 + h_2 + h_3 = \mathbf{2500}$ mm

Weight of gabion 4; $W_{g4} = \gamma_d \times w_4 \times h_4 = \mathbf{24.0}$ kN/m

Horizontal distance to centre of gravity gabion 5; $x_{g5} = w_5 / 2 + s_3 + s_4 + s_5 = \mathbf{2000}$ mm

Vertical distance to centre of gravity gabion 5; $y_{g5} = h_5 / 2 + h_2 + h_3 + h_4 = \mathbf{3500}$ mm

Weight of gabion 5; $W_{g5} = \gamma_d \times w_5 \times h_5 = \mathbf{16.0}$ kN/m

Weight of entire gabion; $W_g = W_{g2} + W_{g3} + W_{g4} + W_{g5} = \mathbf{112.0}$ kN/m

Horiz distance to centre of gravity entire gabion; $x_g = ((W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4}) + (W_{g5} \times x_{g5})) / W_g = \mathbf{1536}$ mm

Vert distance to centre of gravity entire gabion; $y_g = ((W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4}) + (W_{g5} \times y_{g5})) / W_g = \mathbf{1643}$ mm

Correction for wall inclination horiz dist; $X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) = \mathbf{1536}$ mm

Vertical change in height due to wall inclination; $H_f = y_{g5} + h_5/2 - ((y_{g5} + h_5/2) \times \cos(\varepsilon) - (x_{g5} + w_5/2) \times \sin(\varepsilon)) = \mathbf{0}$ mm

Design dimensions

Effective angle of rear plane of wall; α = 90 deg + ε = **90.0** deg

Effective face angle; $\theta = \mathrm{Atan}((y_{g5} + (h_5 / 2)) / ((x_{g5} - (w_5 / 2)))) - \varepsilon$ = **69.4** deg

Effective height of wall; $H = (y_{g5} + h_5 / 2) + (w_2 \times \sin(\varepsilon)) - H_f$ = **4000** mm

Height of wall from toe to front edge of top gabion; $H_{incl} = ((y_{g5} + h_5 / 2) \times \cos(\varepsilon) - (x_{g5} - (w_5 / 2)) \times \sin(\varepsilon))$ = **4000**mm

Active pressure using Coulomb theory; $K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times (1 + \sqrt{(\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))})^2)$ = **0.296**

Active thrust due to soil; $P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2$ = **49.8** kN/m

Horizontal forces

Retained soil; $F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d})$ = **62.1** kN/m

Line loading; $F_{line\_h} = F_{h,Q} \times \gamma_Q$ = **1.5** kN/m

Vertical forces

Gabion weight; $F_{gabion\_v,f} = \gamma_{G,f} \times W_g$ = **112.0** kN/m

Retained soil; $F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d})$ = **19.0** kN/m

Line loading; $F_{line\_v,f} = (F_{v,G} \times \gamma_{G,f} + F_{v,Q} \times \gamma_{Q,f})$ = **5.0** kN/m

Overturning stability - take moments about the toe

Overturning moment; $M_o = F_{soil\_h} \times d_{h,soil} + F_{line\_h} \times d_{h,line}$ = **88.8** kNm/m

Restoring moment; $M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{line\_v,f} \times b_{v,line}$ = **229.6** kNm/m

Factor of safety; $FoS_M = M_R / M_o$ = **2.586**

Allowable factor of safety; FoS_{M_allow} = **1.000**

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force; $T = F_{soil\_h} + F_{line\_h}$ = **63.6** kN/m

Total vertical force; $N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{line\_v,f}$ = **136.0** kN/m

Sliding force; $F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon)$ = **63.6** kN/m

Sliding resistance; $F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bg.d})$ = **95.3** kN/m

Factor of safety; $FoS_S = F_R / F_f$ = **1.498**

Allowable factor of safety; FoS_{S_allow} = **1.000**

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

<u>Check overturning and sliding between courses 2 and 3</u>

Wall geometry

Horizontal distance to centre of gravity gabion 3; $x_{g3} = w_3 / 2$ = **1000** mm

Vertical distance to centre of gravity gabion 3; $y_{g3} = h_3 / 2$ = **500** mm

Weight of gabion 3; $W_{g3} = \gamma_d \times w_3 \times h_3$ = **32.0** kN/m

Horizontal distance to centre of gravity gabion 4; $x_{g4} = w_4 / 2 + s_4$ = **1250** mm

Vertical distance to centre of gravity gabion 4; $y_{g4} = h_4 / 2 + h_3$ = **1500** mm

Weight of gabion 4; $W_{g4} = \gamma_d \times w_4 \times h_4$ = **24.0** kN/m

Horizontal distance to centre of gravity gabion 5; $x_{g5} = w_5 / 2 + s_4 + s_5$ = **1500** mm

Vertical distance to centre of gravity gabion 5; $y_{g5} = h_5 / 2 + h_3 + h_4$ = **2500** mm

Weight of gabion 5; $W_{g5} = \gamma_d \times w_5 \times h_5$ = **16.0** kN/m

Weight of entire gabion; $W_g = W_{g3} + W_{g4} + W_{g5}$ = **72.0** kN/m

Horiz distance to centre of gravity entire gabion; $x_g = ((W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4}) + (W_{g5} \times x_{g5})) / W_g$ = **1194** mm

Vert distance to centre of gravity entire gabion; $y_g = ((W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4}) + (W_{g5} \times y_{g5})) / W_g$ = **1278** mm

Correcting for wall inclination horiz dist; $X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon)$ = **1194** mm

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Vertical change in height due to wall inclination; $H_f = y_{g5} + h_5/2 - ((y_{g5} + h_5/2) \times \cos(\varepsilon) - (x_{g5} + w_5/2) \times \sin(\varepsilon)) = \mathbf{0}$ mm

Design dimensions

Effective angle of rear plane of wall; $\alpha = 90\text{ deg} + \varepsilon = \mathbf{90.0}$ deg

Effective face angle; $\theta = \mathrm{Atan}((y_{g5} + (h_5 / 2)) / ((x_{g5} - (w_5 / 2)))) - \varepsilon = \mathbf{71.6}$ deg

Effective height of wall; $H = (y_{g5} + h_5 / 2) + (w_3 \times \sin(\varepsilon)) - H_f = \mathbf{3000}$ mm

Height of wall from toe to front edge of top gabion; $H_{incl} = ((y_{g5} + h_5 / 2) \times \cos(\varepsilon) - (x_{g5} - (w_5 / 2)) \times \sin(\varepsilon)) = \mathbf{3000}$mm

Active pressure using Coulomb theory; $K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times (1 + \sqrt{}(\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))))^2) = \mathbf{0.296}$

Active thrust due to soil; $P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2 = \mathbf{28.0}$ kN/m

Horizontal forces

Retained soil; $F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d}) = \mathbf{34.9}$ kN/m

Line loading; $F_{line\_h} = F_{h,Q} \times \gamma_Q = \mathbf{1.5}$ kN/m

Vertical forces

Gabion weight; $F_{gabion\_v,f} = \gamma_{G,f} \times W_g = \mathbf{72.0}$ kN/m

Retained soil; $F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d}) = \mathbf{10.7}$ kN/m

Line loading; $F_{line\_v,f} = (F_{v,G} \times \gamma_{G,f} + F_{v,Q} \times \gamma_{Q,f}) = \mathbf{5.0}$ kN/m

Overturning stability - take moments about the toe

Overturning moment; $M_o = F_{soil\_h} \times d_{h,soil} + F_{line\_h} \times d_{h,line} = \mathbf{39.4}$ kNm/m

Restoring moment; $M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{line\_v,f} \times b_{v,line} = \mathbf{114.9}$ kNm/m

Factor of safety; $FoS_M = M_R / M_o = \mathbf{2.915}$

Allowable factor of safety; $FoS_{M\_allow} = \mathbf{1.000}$

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force; $T = F_{soil\_h} + F_{line\_h} = \mathbf{36.4}$ kN/m

Total vertical force; $N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{line\_v,f} = \mathbf{87.7}$ kN/m

Sliding force; $F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) = \mathbf{36.4}$ kN/m

Sliding resistance; $F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bg.d}) = \mathbf{61.4}$ kN/m

Factor of safety; $FoS_S = F_R / F_f = \mathbf{1.686}$

Allowable factor of safety; $FoS_{S\_allow} = \mathbf{1.000}$

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

Check overturning and sliding between courses 3 and 4

Wall geometry

Horizontal distance to centre of gravity gabion 4; $x_{g4} = w_4 / 2 = \mathbf{750}$ mm

Vertical distance to centre of gravity gabion 4; $y_{g4} = h_4 / 2 = \mathbf{500}$ mm

Weight of gabion 4; $W_{g4} = \gamma_d \times w_4 \times h_4 = \mathbf{24.0}$ kN/m

Horizontal distance to centre of gravity gabion 5; $x_{g5} = w_5 / 2 + s_5 = \mathbf{1000}$ mm

Vertical distance to centre of gravity gabion 5; $y_{g5} = h_5 / 2 + h_4 = \mathbf{1500}$ mm

Weight of gabion 5; $W_{g5} = \gamma_d \times w_5 \times h_5 = \mathbf{16.0}$ kN/m

Weight of entire gabion; $W_g = W_{g4} + W_{g5} = \mathbf{40.0}$ kN/m

Horiz distance to centre of gravity entire gabion; $x_g = ((W_{g4} \times x_{g4}) + (W_{g5} \times x_{g5})) / W_g = \mathbf{850}$ mm

Vert distance to centre of gravity entire gabion; $y_g = ((W_{g4} \times y_{g4}) + (W_{g5} \times y_{g5})) / W_g = \mathbf{900}$ mm

Correcting for wall inclination horiz dist; $X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) = \mathbf{850}$ mm

Vertical change in height due to wall inclination; $H_f = y_{g5} + h_5/2 - ((y_{g5} + h_5/2) \times \cos(\varepsilon) - (x_{g5} + w_5/2) \times \sin(\varepsilon)) = \mathbf{0}$ mm

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Design dimensions

Effective angle of rear plane of wall; α = 90 deg + ε = **90.0** deg

Effective face angle; θ = Atan((y_{g5} + (h_5 / 2)) / ((x_{g5} - (w_5 / 2)))) - ε = **76.0** deg

Effective height of wall; H = (y_{g5} + h_5 / 2) + (w_4 × sin(ε)) - H_f = **2000** mm

Height of wall from toe to front edge of top gabion; H_{incl} = ((y_{g5} + h_5 / 2) × cos(ε) - (x_{g5} - (w_5 / 2)) × sin(ε)) = **2000**mm

Active pressure using Coulomb theory; K_a = sin(α + $\phi'_{r.d}$)^2 / (sin(α)^2 × sin(α - $\delta_{r.d}$) × (1 + √(sin($\phi'_{r.d}$ + $\delta_{r.d}$) × sin($\phi'_{r.d}$ - β) / (sin(α - $\delta_{r.d}$) × sin(α + β))))^2) = **0.296**

Active thrust due to soil; $P_{a,soil}$ = 0.5 × K_a × $\gamma_{s.d}$ × H^2 = **12.4** kN/m

Horizontal forces

Retained soil; F_{soil_h} = γ_G × $P_{a,soil}$ × cos(90 - α + $\delta_{r.d}$) = **15.5** kN/m

Line loading; F_{line_h} = $F_{h,Q}$ × γ_Q = **1.5** kN/m

Vertical forces

Gabion weight; $F_{gabion\_v,f}$ = $\gamma_{G,f}$ × W_g = **40.0** kN/m

Retained soil; $F_{soil\_v,f}$ = $\gamma_{G,f}$ × $P_{a,soil}$ × sin(90 - α + $\delta_{r.d}$) = **4.8** kN/m

Line loading; $F_{line\_v,f}$ = ($F_{v,G}$ × $\gamma_{G,f}$ + $F_{v,Q}$ × $\gamma_{Q,f}$) = **5.0** kN/m

Overturning stability - take moments about the toe

Overturning moment; M_o = F_{soil_h} × $d_{h,soil}$ + F_{line_h} × $d_{h,line}$ = **13.3** kNm/m

Restoring moment; M_R = $F_{gabion\_v,f}$ × X_g + $F_{soil\_v,f}$ × $b_{v,soil}$ + $F_{line\_v,f}$ × $b_{v,line}$ = **46.1** kNm/m

Factor of safety; FoS_M = M_R / M_o = **3.457**

Allowable factor of safety; FoS_{M_allow} = **1.000**

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force; T = F_{soil_h} + F_{line_h} = **17.0** kN/m

Total vertical force; N = $F_{gabion\_v,f}$ + $F_{soil\_v,f}$ + $F_{line\_v,f}$ = **49.8** kN/m

Sliding force; F_f = T × cos(ε) - N × sin(ε) = **17.0** kN/m

Sliding resistance; F_R = (T × sin(ε) + N × cos(ε)) × tan($\delta_{bg.d}$) = **34.8** kN/m

Factor of safety; FoS_S = F_R / F_f = **2.047**

Allowable factor of safety; FoS_{S_allow} = **1.000**

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

Check overturning and sliding between courses 4 and 5

Wall geometry

Horizontal distance to centre of gravity gabion 5; x_{g5} = w_5 / 2 = **500** mm

Vertical distance to centre of gravity gabion 5; y_{g5} = h_5 / 2 = **500** mm

Weight of gabion 5; W_{g5} = γ_d × w_5 × h_5 = **16.0** kN/m

Weight of entire gabion; W_g = W_{g5} = **16.0** kN/m

Horiz distance to centre of gravity entire gabion; x_g = ((W_{g5} × x_{g5})) / W_g = **500** mm

Vert distance to centre of gravity entire gabion; y_g = ((W_{g5} × y_{g5})) / W_g = **500** mm

Correcting for wall inclination horiz dist; X_g = x_g × cos(ε) + y_g × sin(ε) = **500** mm

Vertical change in height due to wall inclination; H_f = y_{g5} + h_5/2 - ((y_{g5} + h_5/2) × cos(ε) - (x_{g5} + w_5/2) × sin(ε)) = **0** mm

Design dimensions

Effective angle of rear plane of wall; α = 90 deg + ε = **90.0** deg

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Effective face angle; θ = 90deg - ε = **90.0** deg

Effective height of wall; H = (y_{g5} + h_5 / 2) + (w_5 × sin(ε)) - H_f = **1000** mm

Height of wall from toe to front edge of top gabion; H_{incl} = ((y_{g5} + h_5 / 2) × cos(ε) - (x_{g5} - (w_5 / 2)) × sin(ε)) = **1000**mm

Active pressure using Coulomb theory; $K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times (1 + \sqrt{(\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta)))})^2) = \mathbf{0.296}$

Active thrust due to soil; $P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2 =$ **3.1** kN/m

Horizontal forces

Retained soil; $F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d}) =$ **3.9** kN/m

Line loading; $F_{line\_h} = F_{h,Q} \times \gamma_Q =$ **1.5** kN/m

Vertical forces

Gabion weight; $F_{gabion\_v,f} = \gamma_{G,f} \times W_g =$ **16.0** kN/m

Retained soil; $F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d}) =$ **1.2** kN/m

Line loading; $F_{line\_v,f} = (F_{v,G} \times \gamma_{G,f} + F_{v,Q} \times \gamma_{Q,f}) =$ **5.0** kN/m

Overturning stability - take moments about the toe

Overturning moment; $M_o = F_{soil\_h} \times d_{h,soil} + F_{line\_h} \times d_{h,line} =$ **2.8** kNm/m

Restoring moment; $M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{line\_v,f} \times b_{v,line} =$ **11.7** kNm/m

Factor of safety; $FoS_M = M_R / M_o =$ **4.185**

Allowable factor of safety; $FoS_{M\_allow} =$ **1.000**

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force; $T = F_{soil\_h} + F_{line\_h} =$ **5.4** kN/m

Total vertical force; $N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{line\_v,f} =$ **22.2** kN/m

Sliding force; $F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) =$ **5.4** kN/m

Sliding resistance; $F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bg.d}) =$ **15.5** kN/m

Factor of safety; $FoS_S = F_R / F_f =$ **2.888**

Allowable factor of safety; $FoS_{S\_allow} =$ **1.000**

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

Design approach 1

Partial factors on actions - Section A.3.1 - Combination 2

Permanent unfavourable action; $\gamma_G =$ **1.00**

Permanent favourable action; $\gamma_{G,f} =$ **1.00**

Variable unfavourable action; $\gamma_Q =$ **1.30**

Variable favourable action; $\gamma_{Q,f} =$ **0.00**

Partial factors for soil parameters - Section A.3.2 - Combination 2

Angle of shearing resistance; $\gamma_{\phi'} =$ **1.25**

Weight density; $\gamma_\gamma =$ **1.00**

Design soil properties

Design effective shearing resistance angle; $\phi'_{r.d} = \mathrm{Atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'}) =$ **24.8** deg

Design saturated density of retained soil; $\gamma_{s.d} = \gamma_{sr} / \gamma_\gamma =$ **21.0** kN/m^3

Design wall friction angle; $\delta_{r.d} = \min(\mathrm{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'}), \phi'_{r.d} \times k_{membrane}) =$ **18.3** deg

Design base friction angle; $\delta_{bb.d} = \mathrm{Atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'}) =$ **24.8** deg

Design friction between gabions; $\delta_{bg.d} = \mathrm{Atan}(\tan(\delta_{bg.k}) / \gamma_{\phi'}) =$ **29.3** deg

Wall geometry

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Horizontal distance to centre of gravity gabion 1; $x_{g1} = w_1 / 2 =$ **1500** mm

Vertical distance to centre of gravity gabion 1; $y_{g1} = h_1 / 2 =$ **500** mm

Weight of gabion 1; $W_{g1} = \gamma_d \times w_1 \times h_1 =$ **48.0** kN/m

Horizontal distance to centre of gravity gabion 2; $x_{g2} = w_2 / 2 + s_2 =$ **1750** mm

Vertical distance to centre of gravity gabion 2;	$y_{g2} = h_2 / 2 + h_1 =$ **1500** mm
Weight of gabion 2;	$W_{g2} = \gamma_d \times w_2 \times h_2 =$ **40.0** kN/m
Horizontal distance to centre of gravity gabion 3;	$x_{g3} = w_3 / 2 + s_2 + s_3 =$ **2000** mm
Vertical distance to centre of gravity gabion 3;	$y_{g3} = h_3 / 2 + h_1 + h_2 =$ **2500** mm
Weight of gabion 3;	$W_{g3} = \gamma_d \times w_3 \times h_3 =$ **32.0** kN/m
Horizontal distance to centre of gravity gabion 4;	$x_{g4} = w_4 / 2 + s_2 + s_3 + s_4 =$ **2250** mm
Vertical distance to centre of gravity gabion 4;	$y_{g4} = h_4 / 2 + h_1 + h_2 + h_3 =$ **3500** mm
Weight of gabion 4;	$W_{g4} = \gamma_d \times w_4 \times h_4 =$ **24.0** kN/m
Horizontal distance to centre of gravity gabion 5;	$x_{g5} = w_5 / 2 + s_2 + s_3 + s_4 + s_5 =$ **2500** mm
Vertical distance to centre of gravity gabion 5;	$y_{g5} = h_5 / 2 + h_1 + h_2 + h_3 + h_4 =$ **4500** mm
Weight of gabion 5;	$W_{g5} = \gamma_d \times w_5 \times h_5 =$ **16.0** kN/m
Weight of entire gabion;	$W_g = W_{g1} + W_{g2} + W_{g3} + W_{g4} + W_{g5} =$ **160.0** kN/m
Horiz distance to centre of gravity entire gabion;	$x_g = ((W_{g1} \times x_{g1}) + (W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4}) + (W_{g5} \times x_{g5})) / W_g =$ **1875** mm
Vert distance to centre of gravity entire gabion;	$y_g = ((W_{g1} \times y_{g1}) + (W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4}) + (W_{g5} \times y_{g5})) / W_g =$ **2000** mm
Correcting for wall inclination horiz dist;	$X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) =$ **1875** mm
Vertical change in height due to wall inclination;	$H_f = y_{g5} + h_5/2 - ((y_{g5} + h_5/2) \times \cos(\varepsilon) - (x_{g5} + w_5/2) \times \sin(\varepsilon)) =$ **0** mm

Design dimensions

Effective angle of rear plane of wall;	$\alpha = 90 \text{ deg} + \varepsilon =$ **90.0** deg
Effective face angle;	$\theta = \text{Atan}((y_{g5} + (h_5 / 2)) / ((x_{g5} - (w_5 / 2)))) - \varepsilon =$ **68.2** deg
Effective height of wall;	$H = (y_{g5} + h_5 / 2) + (w_1 \times \sin(\varepsilon)) - H_f =$ **5000** mm
Height of wall from toe to front edge of top gabion;	$H_{incl} = ((y_{g5} + h_5 / 2) \times \cos(\varepsilon) - (x_{g5} - (w_5 / 2)) \times \sin(\varepsilon)) =$ **5000**mm
Active pressure using Coulomb theory;	$K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times (1 + \sqrt{(\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta)))})^2) =$ **0.362**
Active thrust due to soil;	$P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2 =$ **94.9** kN/m

Horizontal forces

Retained soil;	$F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d}) =$ **90.1** kN/m
Line loading;	$F_{line\_h} = F_{h,Q} \times \gamma_Q =$ **1.3** kN/m

Vertical forces

Gabion weight;	$F_{gabion\_v,f} = \gamma_{G,f} \times W_g =$ **160.0** kN/m
Retained soil;	$F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d}) =$ **29.9** kN/m
Line loading;	$F_{line\_v,f} = (F_{v,G} \times \gamma_{G,f} + F_{v,Q} \times \gamma_{Q,f}) =$ **5.0** kN/m

Overturning stability - take moments about the toe

Overturning moment;	$M_o = F_{soil\_h} \times d_{h,soil} + F_{line\_h} \times d_{h,line} =$ **156.7** kNm/m
Restoring moment;	$M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{line\_v,f} \times b_{v,line} =$ **402.1** kNm/m
Factor of safety;	$FoS_M = M_R / M_o =$ **2.566**
Allowable factor of safety;	$FoS_{M\_allow} =$ **1.000**

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force;	$T = F_{soil\_h} + F_{line\_h} =$ **91.4** kN/m
Total vertical force;	$N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{line\_v,f} =$ **194.9** kN/m
Sliding force;	$F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) =$ **91.4** kN/m
Sliding resistance;	$F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bb.d}) =$ **90.0** kN/m
Factor of safety;	$FoS_S = F_R / F_f =$ **0.985**

Allowable factor of safety; FoS_{S_allow} = **1.000**

FAIL - Min allowable FOS for sliding exceeds design FOS for sliding

<u>Check overturning and sliding between courses 1 and 2</u>

Wall geometry

Horizontal distance to centre of gravity gabion 2; $x_{g2} = w_2 / 2 =$ **1250** mm

Vertical distance to centre of gravity gabion 2; $y_{g2} = h_2 / 2 =$ **500** mm

Weight of gabion 2; $W_{g2} = \gamma_d \times w_2 \times h_2 =$ **40.0** kN/m

Horizontal distance to centre of gravity gabion 3; $x_{g3} = w_3 / 2 + s_3 =$ **1500** mm

Vertical distance to centre of gravity gabion 3; $y_{g3} = h_3 / 2 + h_2 =$ **1500** mm

Weight of gabion 3; $W_{g3} = \gamma_d \times w_3 \times h_3 =$ **32.0** kN/m

Horizontal distance to centre of gravity gabion 4; $x_{g4} = w_4 / 2 + s_3 + s_4 =$ **1750** mm

Vertical distance to centre of gravity gabion 4; $y_{g4} = h_4 / 2 + h_2 + h_3 =$ **2500** mm

Weight of gabion 4; $W_{g4} = \gamma_d \times w_4 \times h_4 =$ **24.0** kN/m

Horizontal distance to centre of gravity gabion 5; $x_{g5} = w_5 / 2 + s_3 + s_4 + s_5 =$ **2000** mm

Vertical distance to centre of gravity gabion 5; $y_{g5} = h_5 / 2 + h_2 + h_3 + h_4 =$ **3500** mm

Weight of gabion 5; $W_{g5} = \gamma_d \times w_5 \times h_5 =$ **16.0** kN/m

Weight of entire gabion; $W_g = W_{g2} + W_{g3} + W_{g4} + W_{g5} =$ **112.0** kN/m

Horiz distance to centre of gravity entire gabion; $x_g = ((W_{g2} \times x_{g2}) + (W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4}) + (W_{g5} \times x_{g5})) / W_g =$ **1536** mm

Vert distance to centre of gravity entire gabion; $y_g = ((W_{g2} \times y_{g2}) + (W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4}) + (W_{g5} \times y_{g5})) / W_g =$ **1643** mm

Correcting for wall inclination horiz dist; $X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) =$ **1536** mm

Vertical change in height due to wall inclination; $H_f = y_{g5} + h_5/2 - ((y_{g5} + h_5/2) \times \cos(\varepsilon) - (x_{g5} + w_5/2) \times \sin(\varepsilon)) =$ **0** mm

Design dimensions

Effective angle of rear plane of wall; $\alpha = 90 \text{ deg} + \varepsilon =$ **90.0** deg

Effective face angle; $\theta = \text{Atan}((y_{g5} + (h_5 / 2)) / ((x_{g5} - (w_5 / 2)))) - \varepsilon =$ **69.4** deg

Effective height of wall; $H = (y_{g5} + h_5 / 2) + (w_2 \times \sin(\varepsilon)) - H_f =$ **4000** mm

Height of wall from toe to front edge of top gabion; $H_{incl} = ((y_{g5} + h_5 / 2) \times \cos(\varepsilon) - (x_{g5} - (w_5 / 2)) \times \sin(\varepsilon)) =$ **4000**mm

Active pressure using Coulomb theory; $K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times (1 + \sqrt{(\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta)))})^2) =$ **0.362**

Active thrust due to soil; $P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2 =$ **60.8** kN/m

Horizontal forces

Retained soil; $F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d}) =$ **57.7** kN/m

Line loading; $F_{line\_h} = F_{h,Q} \times \gamma_Q =$ **1.3** kN/m

Vertical forces

Gabion weight; $F_{gabion\_v,f} = \gamma_{G,f} \times W_g =$ **112.0** kN/m

Retained soil; $F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d}) =$ **19.1** kN/m

Line loading; $F_{line\_v,f} = (F_{v,G} \times \gamma_{G,f} + F_{v,Q} \times \gamma_{Q,f}) =$ **5.0** kN/m

Overturning stability - take moments about the toe

Overturning moment; $M_o = F_{soil\_h} \times d_{h,soil} + F_{line\_h} \times d_{h,line} =$ **82.1** kNm/m

Restoring moment; $M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{line\_v,f} \times b_{v,line} =$ **229.8** kNm/m

Factor of safety; $FoS_M = M_R / M_o =$ **2.799**

Allowable factor of safety; FoS_{M_allow} = **1.000**

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PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force; $T = F_{soil\_h} + F_{line\_h} =$ **59.0** kN/m

Total vertical force; $N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{line\_v,f}$ = **136.1** kN/m

Sliding force; $F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon)$ = **59.0** kN/m

Sliding resistance; $F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bg.d})$ = **76.2** kN/m

Factor of safety; $FoS_S = F_R / F_f$ = **1.293**

Allowable factor of safety; FoS_{S_allow} = **1.000**

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

<u>Check overturning and sliding between courses 2 and 3</u>

Wall geometry

Horizontal distance to centre of gravity gabion 3; $x_{g3} = w_3 / 2$ = **1000** mm

Vertical distance to centre of gravity gabion 3; $y_{g3} = h_3 / 2$ = **500** mm

Weight of gabion 3; $W_{g3} = \gamma_d \times w_3 \times h_3$ = **32.0** kN/m

Horizontal distance to centre of gravity gabion 4; $x_{g4} = w_4 / 2 + s_4$ = **1250** mm

Vertical distance to centre of gravity gabion 4; $y_{g4} = h_4 / 2 + h_3$ = **1500** mm

Weight of gabion 4; $W_{g4} = \gamma_d \times w_4 \times h_4$ = **24.0** kN/m

Horizontal distance to centre of gravity gabion 5; $x_{g5} = w_5 / 2 + s_4 + s_5$ = **1500** mm

Vertical distance to centre of gravity gabion 5; $y_{g5} = h_5 / 2 + h_3 + h_4$ = **2500** mm

Weight of gabion 5; $W_{g5} = \gamma_d \times w_5 \times h_5$ = **16.0** kN/m

Weight of entire gabion; $W_g = W_{g3} + W_{g4} + W_{g5}$ = **72.0** kN/m

Horiz distance to centre of gravity entire gabion; $x_g = ((W_{g3} \times x_{g3}) + (W_{g4} \times x_{g4}) + (W_{g5} \times x_{g5})) / W_g$ = **1194** mm

Vert distance to centre of gravity entire gabion; $y_g = ((W_{g3} \times y_{g3}) + (W_{g4} \times y_{g4}) + (W_{g5} \times y_{g5})) / W_g$ = **1278** mm

Correcting for wall inclination horiz dist; $X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon)$ = **1194** mm

Vertical change in height due to wall inclination; $H_f = y_{g5} + h_5/2 - ((y_{g5} + h_5/2) \times \cos(\varepsilon) - (x_{g5} + w_5/2) \times \sin(\varepsilon))$ = **0** mm

Design dimensions

Effective angle of rear plane of wall; $\alpha = 90 \text{ deg} + \varepsilon$ = **90.0** deg

Effective face angle; $\theta = \text{Atan}((y_{g5} + (h_5 / 2)) / ((x_{g5} - (w_5 / 2)))) - \varepsilon$ = **71.6** deg

Effective height of wall; $H = (y_{g5} + h_5 / 2) + (w_3 \times \sin(\varepsilon)) - H_f$ = **3000** mm

Height of wall from toe to front edge of top gabion; $H_{incl} = ((y_{g5} + h_5 / 2) \times \cos(\varepsilon) - (x_{g5} - (w_5 / 2)) \times \sin(\varepsilon))$ = **3000**mm

Active pressure using Coulomb theory; $K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times (1 + \sqrt{(\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta)))})^2)$ = **0.362**

Active thrust due to soil; $P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2$ = **34.2** kN/m

Horizontal forces

Retained soil; $F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d})$ = **32.4** kN/m

Line loading; $F_{line\_h} = F_{h,Q} \times \gamma_Q$ = **1.3** kN/m

Vertical forces

Gabion weight; $F_{gabion\_v,f} = \gamma_{G,f} \times W_g$ = **72.0** kN/m

Retained soil; $F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d})$ = **10.7** kN/m

Line loading; $F_{line\_v,f} = (F_{v,G} \times \gamma_{G,f} + F_{v,Q} \times \gamma_{Q,f})$ = **5.0** kN/m

Overturning stability - take moments about the toe

Overturning moment; $M_o = F_{soil\_h} \times d_{h,soil} + F_{line\_h} \times d_{h,line}$ = **36.3** kNm/m

Restoring moment; $M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{line\_v,f} \times b_{v,line}$ = **115.0** kNm/m

Factor of safety; $FoS_M = M_R / M_o$ = **3.165**

Allowable factor of safety; FoS_{M_allow} = **1.000**

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PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force; $T = F_{soil\_h} + F_{line\_h} = \mathbf{33.7}$ kN/m

Total vertical force; $N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{line\_v,f} = \mathbf{87.7}$ kN/m

Sliding force; $F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) = \mathbf{33.7}$ kN/m

Sliding resistance; $F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bg.d}) = \mathbf{49.2}$ kN/m

Factor of safety; $FoS_S = F_R / F_f = \mathbf{1.457}$

Allowable factor of safety; $FoS_{S\_allow} = \mathbf{1.000}$

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

<u>Check overturning and sliding between courses 3 and 4</u>

Wall geometry

Horizontal distance to centre of gravity gabion 4; $x_{g4} = w_4 / 2 = \mathbf{750}$ mm

Vertical distance to centre of gravity gabion 4; $y_{g4} = h_4 / 2 = \mathbf{500}$ mm

Weight of gabion 4; $W_{g4} = \gamma_d \times w_4 \times h_4 = \mathbf{24.0}$ kN/m

Horizontal distance to centre of gravity gabion 5; $x_{g5} = w_5 / 2 + s_5 = \mathbf{1000}$ mm

Vertical distance to centre of gravity gabion 5; $y_{g5} = h_5 / 2 + h_4 = \mathbf{1500}$ mm

Weight of gabion 5; $W_{g5} = \gamma_d \times w_5 \times h_5 = \mathbf{16.0}$ kN/m

Weight of entire gabion; $W_g = W_{g4} + W_{g5} = \mathbf{40.0}$ kN/m

Horiz distance to centre of gravity entire gabion; $x_g = ((W_{g4} \times x_{g4}) + (W_{g5} \times x_{g5})) / W_g = \mathbf{850}$ mm

Vert distance to centre of gravity entire gabion; $y_g = ((W_{g4} \times y_{g4}) + (W_{g5} \times y_{g5})) / W_g = \mathbf{900}$ mm

Correcting for wall inclination horiz dist; $X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) = \mathbf{850}$ mm

Vertical change in height due to wall inclination; $H_f = y_{g5} + h_5/2 - ((y_{g5} + h_5/2) \times \cos(\varepsilon) - (x_{g5} + w_5/2) \times \sin(\varepsilon)) = \mathbf{0}$ mm

Design dimensions

Effective angle of rear plane of wall; $\alpha = 90 \text{ deg} + \varepsilon = \mathbf{90.0}$ deg

Effective face angle; $\theta = \text{Atan}((y_{g5} + (h_5 / 2)) / ((x_{g5} - (w_5 / 2)))) - \varepsilon = \mathbf{76.0}$ deg

Effective height of wall; $H = (y_{g5} + h_5 / 2) + (w_4 \times \sin(\varepsilon)) - H_f = \mathbf{2000}$ mm

Height of wall from toe to front edge of top gabion; $H_{incl} = ((y_{g5} + h_5 / 2) \times \cos(\varepsilon) - (x_{g5} - (w_5 / 2)) \times \sin(\varepsilon)) = \mathbf{2000}$mm

Active pressure using Coulomb theory; $K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times (1 + \sqrt{(\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta)))})^2) = \mathbf{0.362}$

Active thrust due to soil; $P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2 = \mathbf{15.2}$ kN/m

Horizontal forces

Retained soil; $F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d}) = \mathbf{14.4}$ kN/m

Line loading; $F_{line\_h} = F_{h,Q} \times \gamma_Q = \mathbf{1.3}$ kN/m

Vertical forces

Gabion weight; $F_{gabion\_v,f} = \gamma_{G,f} \times W_g = \mathbf{40.0}$ kN/m

Retained soil; $F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d}) = \mathbf{4.8}$ kN/m

Line loading; $F_{line\_v,f} = (F_{v,G} \times \gamma_{G,f} + F_{v,Q} \times \gamma_{Q,f}) = \mathbf{5.0}$ kN/m

Overturning stability - take moments about the toe

Overturning moment; $M_o = F_{soil\_h} \times d_{h,soil} + F_{line\_h} \times d_{h,line} = \mathbf{12.2}$ kNm/m

Restoring moment; $M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{line\_v,f} \times b_{v,line} = \mathbf{46.2}$ kNm/m

Factor of safety; $FoS_M = M_R / M_o = \mathbf{3.781}$

Allowable factor of safety; $FoS_{M\_allow} = \mathbf{1.000}$

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PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force; $T = F_{soil\_h} + F_{line\_h} = \mathbf{15.7}$ kN/m

Total vertical force;	$N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{line\_v,f} = \mathbf{49.8}$ kN/m
Sliding force;	$F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) = \mathbf{15.7}$ kN/m
Sliding resistance;	$F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bg.d}) = \mathbf{27.9}$ kN/m
Factor of safety;	$FoS_S = F_R / F_f = \mathbf{1.774}$
Allowable factor of safety;	$FoS_{S\_allow} = \mathbf{1.000}$

PASS - Design FOS for sliding exceeds min allowable FOS for sliding

<u>Check overturning and sliding between courses 4 and 5</u>

Wall geometry

Horizontal distance to centre of gravity gabion 5;	$x_{g5} = w_5 / 2 = \mathbf{500}$ mm
Vertical distance to centre of gravity gabion 5;	$y_{g5} = h_5 / 2 = \mathbf{500}$ mm
Weight of gabion 5;	$W_{g5} = \gamma_d \times w_5 \times h_5 = \mathbf{16.0}$ kN/m
Weight of entire gabion;	$W_g = W_{g5} = \mathbf{16.0}$ kN/m
Horiz distance to centre of gravity entire gabion;	$x_g = ((W_{g5} \times x_{g5})) / W_g = \mathbf{500}$ mm
Vert distance to centre of gravity entire gabion;	$y_g = ((W_{g5} \times y_{g5})) / W_g = \mathbf{500}$ mm
Correcting for wall inclination horiz dist;	$X_g = x_g \times \cos(\varepsilon) + y_g \times \sin(\varepsilon) = \mathbf{500}$ mm
Vertical change in height due to wall inclination;	$H_f = y_{g5} + h_5/2 - ((y_{g5} + h_5/2) \times \cos(\varepsilon) - (x_{g5} + w_5/2) \times \sin(\varepsilon)) = \mathbf{0}$ mm

Design dimensions

Effective angle of rear plane of wall;	$\alpha = 90\text{ deg} + \varepsilon = \mathbf{90.0}$ deg
Effective face angle;	$\theta = 90\text{deg} - \varepsilon = \mathbf{90.0}$ deg
Effective height of wall;	$H = (y_{g5} + h_5 / 2) + (w_5 \times \sin(\varepsilon)) - H_f = \mathbf{1000}$ mm
Height of wall from toe to front edge of top gabion;	$H_{incl} = ((y_{g5} + h_5 / 2) \times \cos(\varepsilon) - (x_{g5} - (w_5 / 2)) \times \sin(\varepsilon)) = \mathbf{1000}$mm
Active pressure using Coulomb theory;	$K_a = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times (1 + \sqrt{}(\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))))^2) = \mathbf{0.362}$
Active thrust due to soil;	$P_{a,soil} = 0.5 \times K_a \times \gamma_{s.d} \times H^2 = \mathbf{3.8}$ kN/m

Horizontal forces

Retained soil;	$F_{soil\_h} = \gamma_G \times P_{a,soil} \times \cos(90 - \alpha + \delta_{r.d}) = \mathbf{3.6}$ kN/m
Line loading;	$F_{line\_h} = F_{h,Q} \times \gamma_Q = \mathbf{1.3}$ kN/m

Vertical forces

Gabion weight;	$F_{gabion\_v,f} = \gamma_{G,f} \times W_g = \mathbf{16.0}$ kN/m
Retained soil;	$F_{soil\_v,f} = \gamma_{G,f} \times P_{a,soil} \times \sin(90 - \alpha + \delta_{r.d}) = \mathbf{1.2}$ kN/m
Line loading;	$F_{line\_v,f} = (F_{v,G} \times \gamma_{G,f} + F_{v,Q} \times \gamma_{Q,f}) = \mathbf{5.0}$ kN/m

Overturning stability - take moments about the toe

Overturning moment;	$M_o = F_{soil\_h} \times d_{h,soil} + F_{line\_h} \times d_{h,line} = \mathbf{2.5}$ kNm/m
Restoring moment;	$M_R = F_{gabion\_v,f} \times X_g + F_{soil\_v,f} \times b_{v,soil} + F_{line\_v,f} \times b_{v,line} = \mathbf{11.7}$ kNm/m
Factor of safety;	$FoS_M = M_R / M_o = \mathbf{4.675}$
Allowable factor of safety;	$FoS_{M\_allow} = \mathbf{1.000}$

PASS - Design FOS for overturning exceeds min allowable FOS for overturning

Sliding stability - ignore any passive pressure in front of the structure

Total horizontal force;	$T = F_{soil\_h} + F_{line\_h} = \mathbf{4.9}$ kN/m
Total vertical force;	$N = F_{gabion\_v,f} + F_{soil\_v,f} + F_{line\_v,f} = \mathbf{22.2}$ kN/m
Sliding force;	$F_f = T \times \cos(\varepsilon) - N \times \sin(\varepsilon) = \mathbf{4.9}$ kN/m
Sliding resistance;	$F_R = (T \times \sin(\varepsilon) + N \times \cos(\varepsilon)) \times \tan(\delta_{bg.d}) = \mathbf{12.4}$ kN/m
Factor of safety;	$FoS_S = F_R / F_f = \mathbf{2.535}$
Allowable factor of safety;	$FoS_{S\_allow} = \mathbf{1.000}$

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PASS - Design FOS for sliding exceeds min allowable FOS for sliding

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