Peat Stability - An Integrated Approach to Risk Management

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Peat Stability -
An Integrated Approach to Risk Management

- Designer's Peat Stability Risk Assessment
- Design and Construction Mitigation Measures
- Construction Control Measures

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Designer’s Peat Stability Risk Assessment

Peat Stability Risk Assessment

- Designers Peat Stability Risk Assessment – should be carried out by designer at detailed design stage in advance construction.
- Should not be a generic risk assessment of each area of the site.
- Should be specific to proposed construction methods and actual ground and groundwater conditions for each element of the works.
- Method of assessment follows general guidelines of Scottish Executive & Mac Culloch but has been developed to look at the interaction between different risk factors to identify high risk areas.
- Also allows a comparison of relative hazard between different parts of the site.
- Method of assesment also takes into account risk factors that have been identified from recent slides that have occurred in Ireland.

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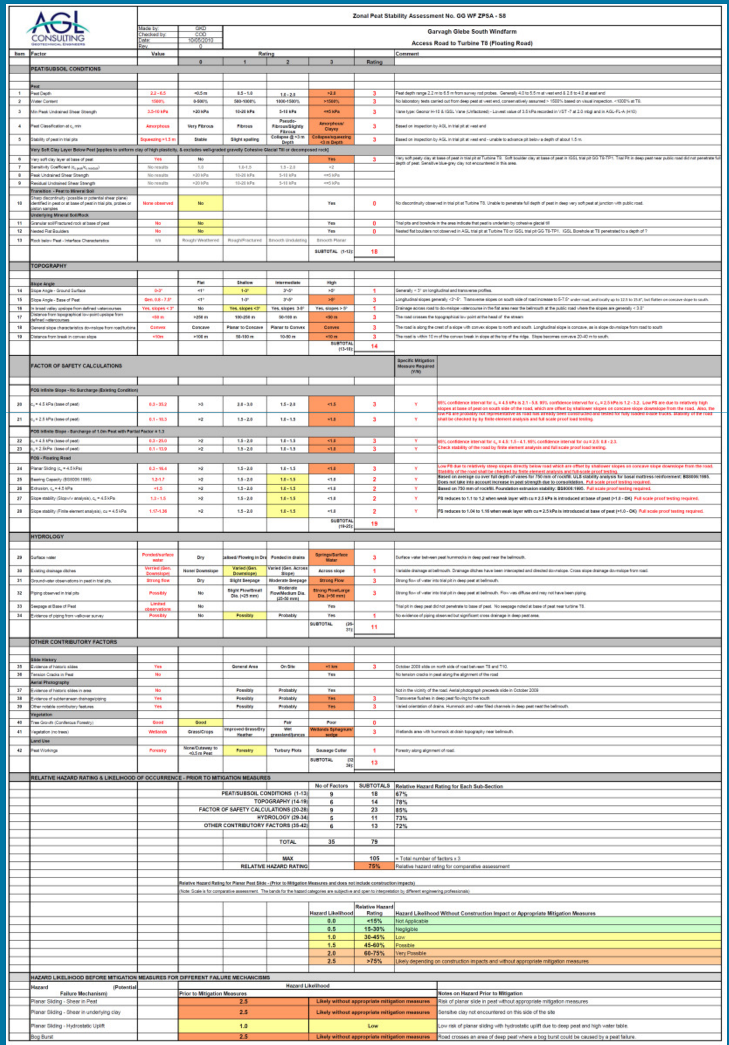
Peat Stability Assessment Worksheet



- Peat/Subsoil Conditions
- Topography
- Factor of Safety Calculations
- Hydrology
- Other Contributory Factors

Peat Stability Assessment – Peat/Subsoil

Item	Factor	Value	Rating				
			0	1	2	3	Rating
	PEAT/SUBSOIL CONDITIONS						
	Peat						
1	Peat Depth	2.2 - 6.5	<0.5 m	0.5 - 1.0	1.0 - 2.0	>2.0	3
2	Water Content	1500%	0-500%	500-1000%	1000-1500%	>1500%	3
3	Min Peak Undrained Shear Strength	3.5-10 kPa	>20 kPa	10-20 kPa	5-10 kPa	<=5 kPa	3
4	Peat Classification at c_u min	Amorphous	Very Fibrous	Fibrous	Pseudo-Fibrous/Slightly Fibrous	Amorphous/ Clayey	3
5	Stability of peat in trial pits	Squeezing >1.5 m	Stable	Slight spalling	Collapse @ >3 m Depth	Collapse/squeezing <3 m Depth	3
	Very Soft Clay Layer Below Peat [applies to uniform clay of high plasticity, & excludes well-graded gravelly Cohesive Glacial Till or decomposed rock]						
6	Very soft clay layer at base of peat	Yes	No			Yes	3
7	Sensitivity Coefficient ($c_{u\,peak}/c_{u\,residual}$)	No results	1.0	1.0-1.5	1.5 - 2.0	>2	
8	Peak Undrained Shear Strength	No results	>20 kPa	10-20 kPa	5-10 kPa	<=5 kPa	
9	Residual Undrained Shear Strength	No results	>20 kPa	10-20 kPa	5-10 kPa	<=5 kPa	
	Transition - Peat to Mineral Soil						
10	Sharp discontinuity (possible or potential shear plane) identified in peat or at base of peat in trial pits, probes or piston samples	None observed	No			Yes	0
	Underlying Mineral Soil/Rock						
11	Granular soil/Fractured rock at base of peat	No	No			Yes	0
12	Nested Flat Boulders	No	No			Yes	0
13	Rock below Peat - Interface Characteristics	n/a	Rough/ Weathered	Rough/Fractured	Smooth Undulating	Smooth Planar	
						SUBTOTAL (1-12):	18

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Peat Stability Assessment – Peat/Subsoil Conditions

Shear Failure in Clay below peat

Sharp transition from peat to clay with remoulded clay at interface

(sample inverted)

Nested flat boulders and seepage at base of peat

Sharp transition within peat from very soft slightly fibrous to soft/firm very fibrous with aligned wood fibres (sample inverted)

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Peat Stability Assessment - Topography

	TOPOGRAPHY						
	Slope Angle		Flat	Shallow	Intermediate	High	
14	Slope Angle - Ground Surface	0-3°	<1°	1-3°	3°-5°	>5°	1
15	Slope Angle - Base of Peat	Gen. 0.8 - 7.5°	<1°	1-3°	3°-5°	>5°	3
16	In broad valley upslope from defined watercourses	Yes, slopes < 3°	No	Yes, slopes <3°	Yes, slopes 3-5°	Yes, slopes > 5°	1
17	Distance from topographical low-point upslope from defined watercourses	<50 m	>250 m	100-250 m	50-100 m	<50 m	3
18	General slope characteristics downslope from road/turbine	Convex	Concave	Planar to Concave	Planar to Convex	Convex	3
19	Distance from break in convex slope	<10m	>100 m	50-100 m	10-50 m	<10 m	3
						SUBTOTAL (13-18):	14

Highest risk areas for a planar slide occur:

- In peat 1.5 – 3.0 m deep
- On slope angles of 4-7°, particularly at a convex break in slope to slopes > 5° (need to consider slope angle at base of peat)
- At the topographical low point directly upslope from a defined watercourse.

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Peat Stability Assessment – FoS Calculations

	FACTOR OF SAFETY CALCULATIONS							Specific Mitigation Measure Required (Y/N)
	FOS Infinite Slope - No Surcharge (Existing Condition)							
20	c_u = 4.5 kPa (base of peat)	0.3 - 35.2	>3	2.0 - 3.0	1.5 - 2.0	<1.5	3	Y
21	c_u = 2.5 kPa (base of peat)	0.1 - 10.3	>2	1.5 - 2.0	1.0 - 1.5	<1.0	3	Y
	FOS Infinite Slope - Surcharge of 1.0m Peat with Partial Factor = 1.3							
22	c_u = 4.5 kPa (base of peat)	0.3 - 25.0	>3	2.0 - 3.0	1.5 - 2.0	<1.5	3	Y
23	c_u = 2.5kPa (base of peat)	0.1 - 13.9	>2	1.5 - 2.0	1.0 - 1.5	<1.0	3	Y
	FOS - Floating Road							
24	Planar Sliding (c_u = 4.5 kPa)	0.3 - 16.4	>2	1.5 - 2.0	1.0 - 1.5	<1.0	3	Y
25	Bearing Capacity (BS8006:1995)	1.43 - 3.53	>2	1.5 - 2.0	1.0 - 1.5	<1.0	2	Y
26	Extrusion	1.30 to 14.4	>2	1.5 - 2.0	1.0 - 1.5	<1.0	2	Y
27	Slope stability (Slopw/w analysis)	1.33 - 1.83	>2	1.5 - 2.0	1.0 - 1.5	<1.0	2	Y
28	Slope stability/Bearing Capacity (Finite element analysis)	1.20 - 1.45	>2	1.5 - 2.0	1.0 - 1.5	<1.0	2	Y
						SUBTOTAL (19-25):	19	

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Peat Stability Assessment – FoS Calculations

$$F = Cu/(\gamma z \sin\beta \cos\beta)$$

Where;

- **Cu** = Shear strength of the peat (kPa)
- γ = Bulk weight of peat (kN/m^3)
- **z** = Depth of Peat (m)
- **β** = Angle of sliding plane (degs)
- **F** = Factor of Safety

Infinite Slope FoS:

- Simplified method of analysis for planar undrained shear failure
- Doesn't take into account complex slope geometry.
- Uesful index of stability under existing condition (no surcharge)
- Calibrate sensitivity of FoS with surcharge of 1.0 m of peat.

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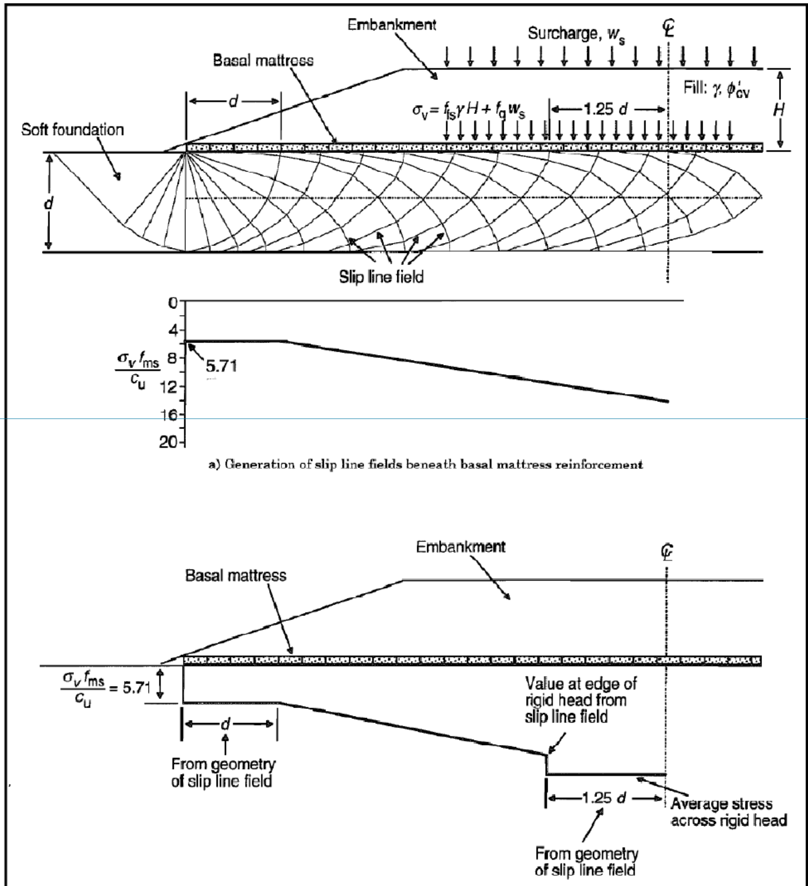
Peat Stability Assessment – FoS Calculations Floating Roads – Bearing Capacity



a) Generation of slip line fields beneath basal mattress reinforcement

b) Bearing pressure diagram for basal mattress reinforcement

BS-8006:1995 – BS Code of Practice for Strengthened/Reinforced Soils

- Method of analysis for calculating ultimate bearing capacity (q_{ult})of embankments over soft ground with basal reinforcement.
- q_{ult} = Nc x c_u
- c_u = Average undrained shear strength of peat
- N_c = stability number = 5.71 for most cases
- FoS = q_{ult}/S
- S = applied surcharge on peat (dead load + live load x 1.3) – assume uniformly distributed

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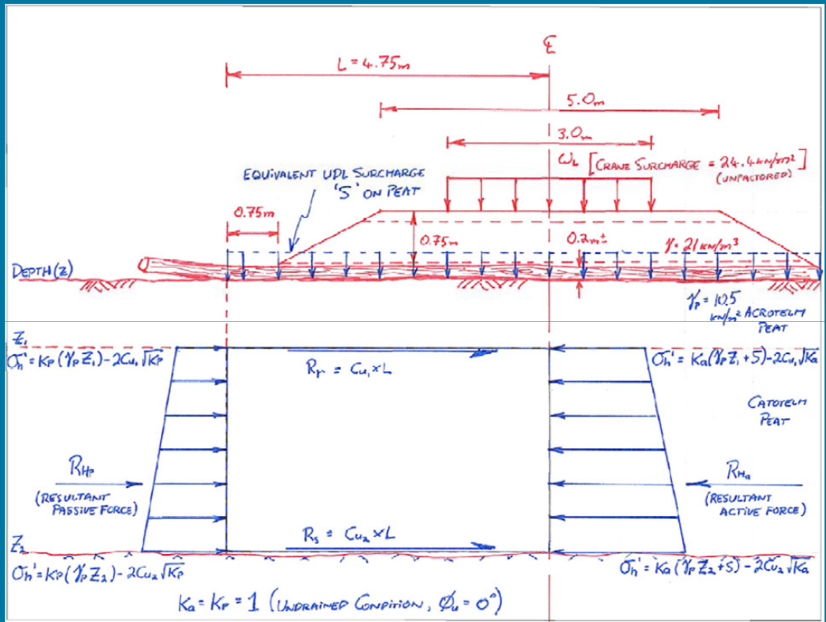
Peat Stability Assessment – FoS Calculations
Floating Roads – Extrusion



Adapted from BS-8006:1995 – BS Code of Practice for Strengthened/Reinforced Soils

- Non-standard method of analysis for calculating FoS against extrusion.

$$FoS_E = [R_{hp} + R_r + R_s]/R_{ha}, \text{ where:}$$

- R_{hp} = Resultant passive force on the block of peat at the edge of the road.
- R_{ha} = Resultant active force on the block of peat at the centre of the road.
- R_r = Shear force along the top of the catotelm peat (or along a weaker layer)
- R_s = Shear force along the base of the peat (or along a weaker layer)

- Useful index of low strength areas but generally a serviceability criterion rather than ultimate limit state (i.e. excessive settlement/deflection)
- Vegetated crust (acrotelm) considered in the analysis.

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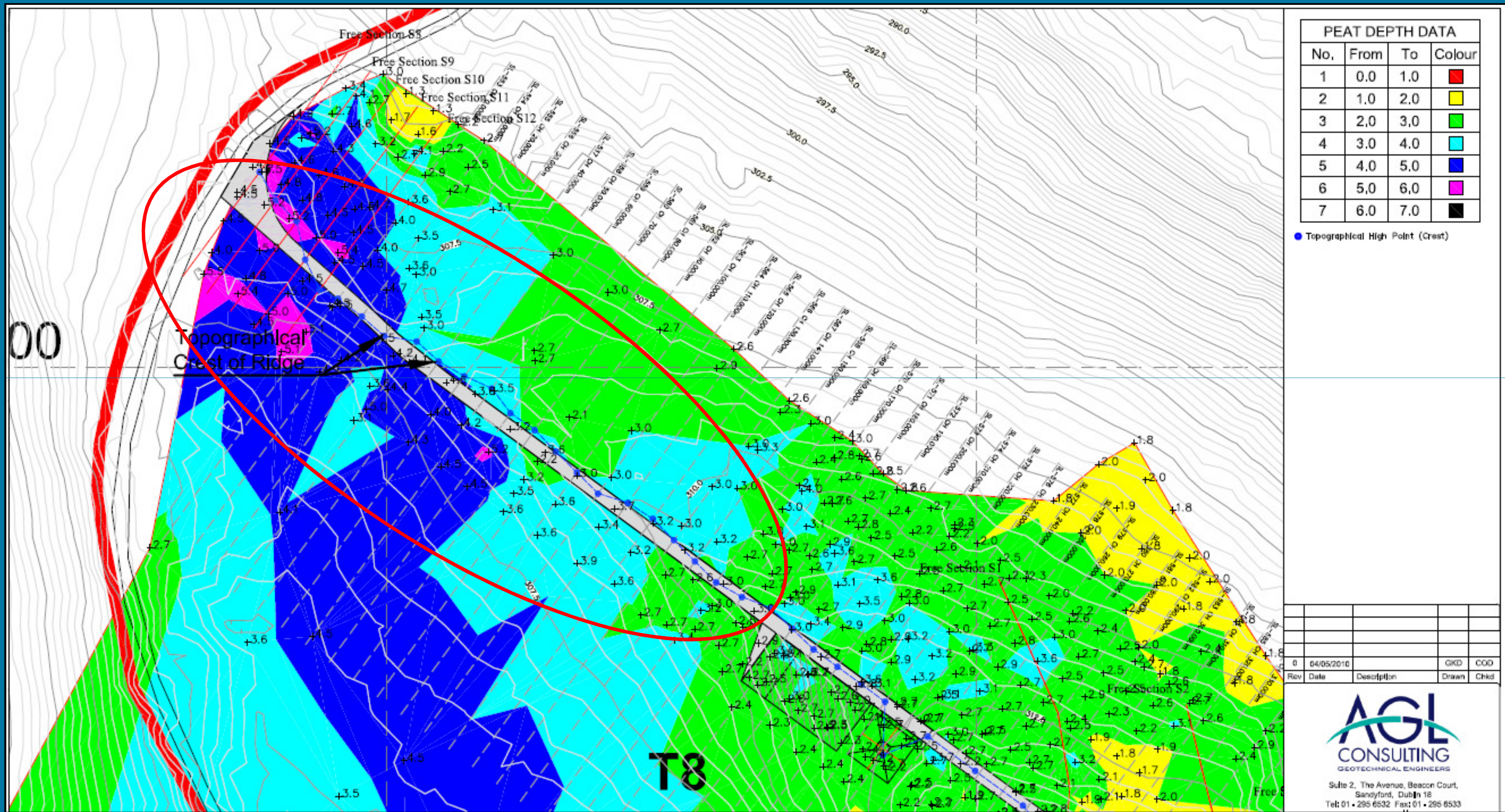
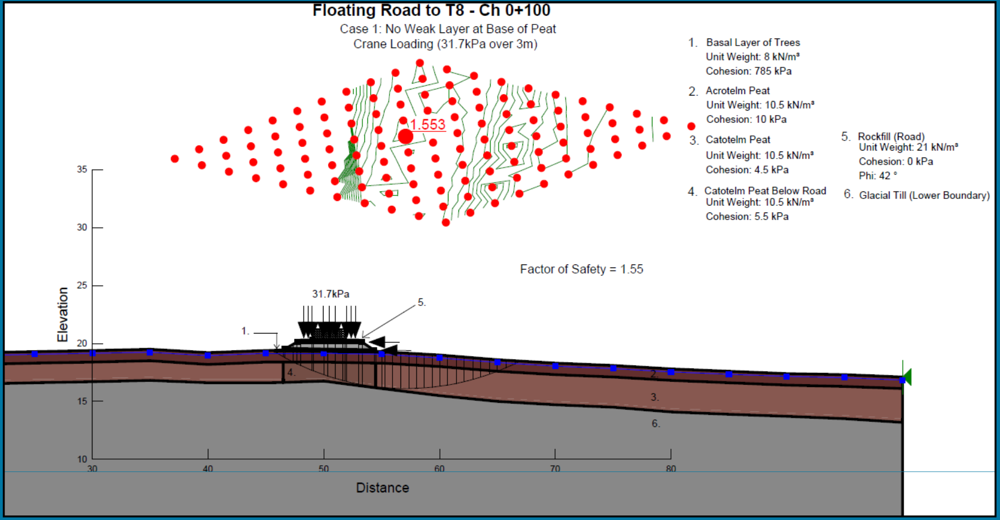
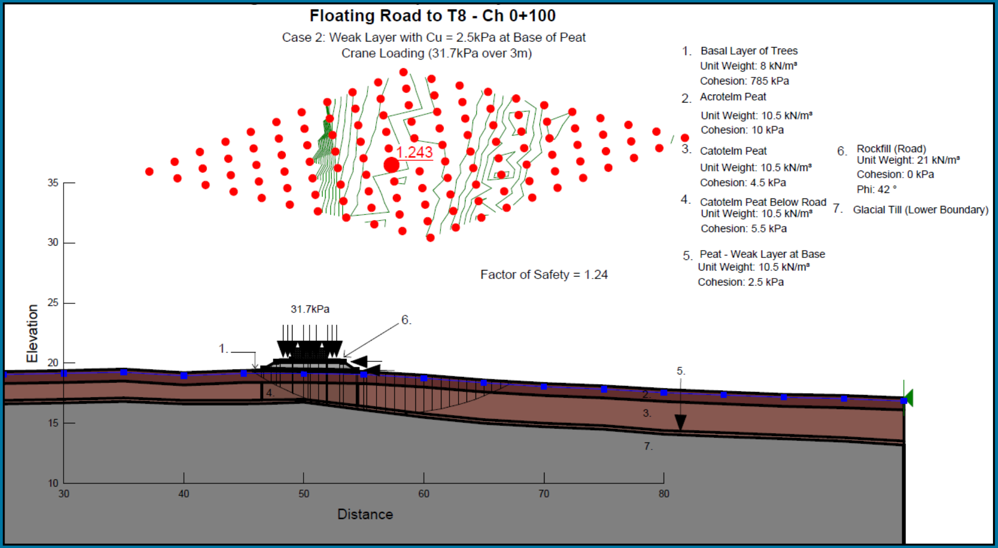
Peat Stability Assessment – FoS Calculations Floating Roads – Slope/W & FEA (Plaxis)



Peat Stability Assessment – FoS Calculations
Floating Roads – Slope/W Analysis





Takes into account

- actual slope geometry & variable depth of peat.
- road structure , geogrid reinforcement, and live load distribution
- Vegetated crust and weak layer (cu = 2.5 kPa) at base of peat.
- FS = 1.55 without weak layer
- FS = 1.23 with weak layer

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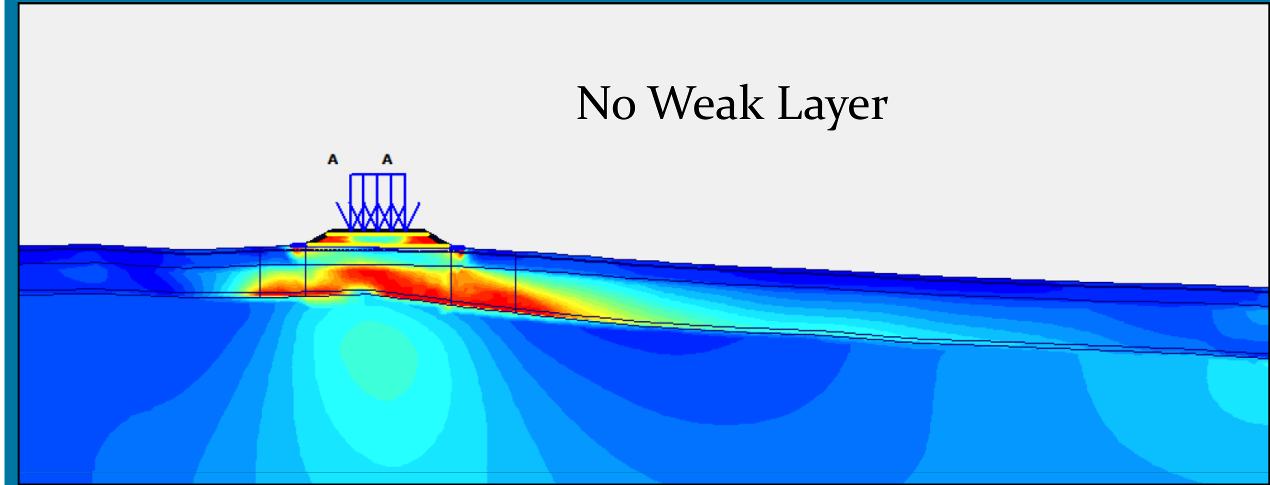
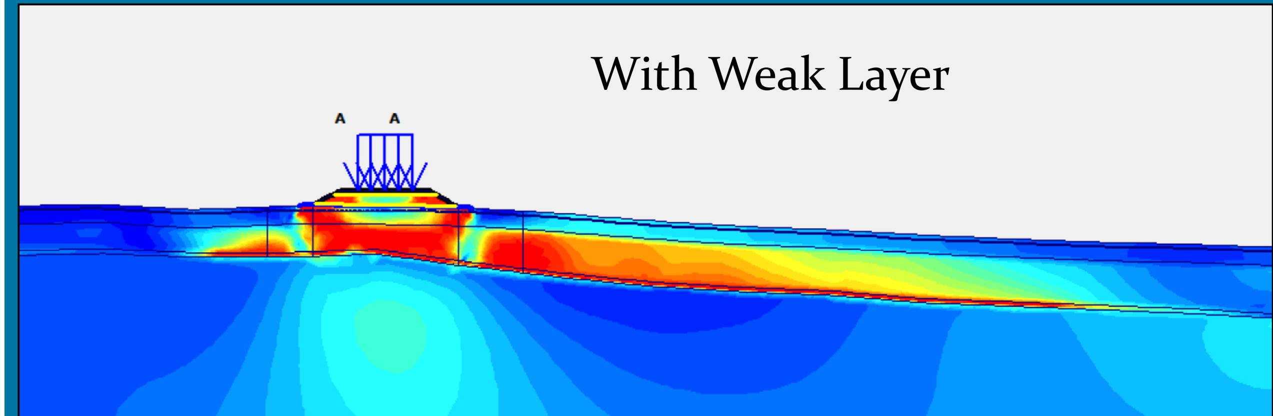
Peat Stability Assessment – FoS Calculations
Floating Roads – Finite Element Analysis





Takes into account :

- actual slope geometry & variable depth of peat.
- Vegetated crust and weak layer (c_u = 2.5 kPa) at base of peat.
- road structure , geogrid reinforcement, and live load distribution
- Staged construction
- FoS calculated using ϕ-c reduction technique
- FS = 1.36 without weak layer
- FS = 1.16 with weak layer

Can analyse distribution of shear stress along the base of the peat.

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Peat Stability Assessment - Hydrology

	HYDROLOGY						
29	Surface water	Ponded/surface water	Dry	calised/ Flowing in Dra	Ponded in drains	Springs/Surface Water	3
30	Existing drainage ditches	Verried (Gen. Downslope)	None/ Downslope	Varied (Gen. Downslope)	Varied (Gen. Across Slope)	Across slope	1
31	Groundwater observations in peat in trial pits.	Strong flow	Dry	Slight Seepage	Moderate Seepage	Strong Flow	3
32	Piping observed in trial pits	Possibly	No	Slight Flow/Small Dia. (<25 mm)	Moderate Flow/Medium Dia. (25-50 mm)	Strong Flow/Large Dia. (>50 mm)	3
33	Seepage at Base of Peat	Limited observations	No			Yes	
34	Evidence of piping from walkover survey	Possibly	No	Possibly	Probably	Yes	1
						SUBTOTAL (26-31):	11

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Peat Stability Assessment - Other Contributory Factors

	OTHER CONTRIBUTORY FACTORS						
	Slide History						
35	Evidence of historic slides	Yes		General Area	On Site	<1 km	3
36	Tension Cracks in Peat	Yes				Yes	3
	Aerial Photography						
37	Evidence of historic slides in area	No		Possibly	Probably	Yes	
38	Evidence of subterranean drainage/piping	Yes		Possibly	Probably	Yes	3
39	Other notable contributory features	Yes		Possibly	Probably	Yes	3
	Vegetation						
40	Tree Growth (Coniferous Forestry)	Good	Good		Fair	Poor	0
41	Vegetation (no trees)	Wetlands	Grass/Crops	Improved Grass/Dry Heather	Wet grassland/juncus	Wetlands Sphagnum/ sedge	3
	Land Use						
42	Peat Workings	Forestry	None/Cutaway to <0.5 m Peat	Forestry	Turbury Plots	Sausage Cutter	2
						SUBTOTAL (32-39):	17

Peat Stability Assessment Worksheet –
Relative Hazard Rating Prior to Mitigation Measures

	No of Factors	SUBTOTALS	Relative Hazard Rating for Each Sub-Section
PEAT/SUBSOIL CONDITIONS (1-13)	9	18	67%
TOPOGRAPHY (14-19)	6	14	78%
FACTOR OF SAFETY CALCULATIONS (20-28)	9	23	85%
HYDROLOGY (29-34)	5	11	73%
OTHER CONTRIBUTORY FACTORS (35-42)	7	17	81%
TOTAL	36	83	
MAX		108	= Total number of factors x 3
RELATIVE HAZARD RATING		77%	Relative hazard rating for comparative assessment

Relative Hazard Rating for Planar Peat Slide - (Prior to Mitigation Measures and does not include construction impacts)

(Note: Scale is for comparative assessment. The bands for the hazard categories are subjective and open to interpretation by different engineering professionals)

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Peat Stability Assessment Worksheet – Relative Hazard Rating

Hazard Likelihood	Relative Hazard Rating	Hazard Likelihood Without Construction Impact or Appropriate Mitigation Measures
0.0	<15%	Not Applicable
1.0	15-30%	Negligible
2.0	30-45%	Low
3.0	45-60%	Possible
4.0	60-75%	Very Possible
5.0	>75%	Likely depending on construction impacts and without appropriate mitigation measures

HAZARD LIKELIHOOD BEFORE MITIGATION MEASURES FOR DIFFERENT FAILURE MECHANCISMS

Hazard (Potential Failure Mechanism)		Hazard Likelihood Prior to Mitigation Measures	
Planar Sliding - Shear in Peat		5.0	Likely without appropriate mitigation measures
Planar Sliding - Shear in underlying clay		5.0	Likely without appropriate mitigation measures
Planar Sliding - Hydrostatic Uplift		2.0	Low
Bog Burst		5.0	Likely without appropriate mitigation measures

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Primary Risk Factors – Planar Sliding (Undrained)

- Peat Depth 1.5 to 3.0 m
- Slope angles 4-7 at a convex break in slope to slopes > 5
- At a topographical low point directly upslope from a defined watercourse.
- Infinite Slope FoS < 1.0 assuming a weak layer with c_u = 2.5 kPa at base of peat.
- Other contributory factors, e.g.
  - Poor drainage and evidence of subsurface flow (flushes/piping/vegetation)
  - Machine cutting (e.g. Sausage cutter, drains across slope)
  - Poor tree growth (sparse/stunted/variable height)
  - Evidence of discontinuity or weak plane in peat (e.g. Sensitive clay layer)
  - Tension cracks, slide history etc.

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Primary Risk Factors – Bog Burst

- Peat Depth > 4.0 m
- Weak, highly amorphous peat with $c_u < 5$ kPa
- Slope angles >3 with proposed works at a convex break in slope.
- Directly upslope from a defined watercourse.
- Ponded surface water with poor drainage and evidence of subsurface seepage/groundwater flow (flushes/piping/vegetation).
- Infinite Slope FoS < 1.0 assuming a weak layer with $c_u = 2.5$ kPa at base of peat.
- Other contributory factors, e.g.
  - Machine cutting (e.g. Sausage cutter, drains across slope)
  - Poor tree growth (sparse/stunted/variable height)
  - Tension cracks, slide history etc.

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Primary Risk Factors – Planar Sliding (Drained/Hydrostatic Uplift)

- Peat Depth < 1.5 m
- Slope angles >7 downslope from a convex break in slope.
- Peat underlain by granular soil, weathered/fractured rock, or nested flat boulders.
- Seepage at base of peat.
- Ponding or concentrated groundwater flow at top of slope
- Extreme rainfall event.
- Other contributory factors, e.g.
  - Poor drainage.
  - Tension cracks, slide history etc.

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Peat Stability Risk Assessment

AGL CONSULTING GEOTECHNICAL ENGINEERS	GEOTECHNICAL RISK REGISTER – PEAT STABILITY		
	Made by	GKD	Windfarm
	Chkd by:	COD	
	Date:	31/05/10	
	Rev:	1	

	Hazard		Risk Rating (R) Prior to Mitigation Measures			Risk Rating (R) After Mitigation Measures		
			L	I	R	L	I	R
1.	Planar Sliding (Undrained)	Shear in Peat	5	5	25	2	5	10
2.	Planar Sliding (Undrained)	Shear in Underlying Clay	5	5	25	2	5	10
3.	Planar Sliding (Drained)	Shear at interface with mineral soil	2	5	10	2	5	10
4.	Bog Burst	Flow Slide/Shear in Peat	5	5	25	2	5	10

Design Risk Mitigation Measures

Peat Stability

1. The bellmouth shall be constructed on the north side of the existing floating road to the dimensions and configuration shown on AGL Drawing No.AGL GGS LSV4 (Rev.0).
2. The bellmouth shall be constructed using the same methods and details as the floating road, i.e.:
    a. The surface of the peat adjacent to the public road shall be trimmed down to approximately 0.5 m below the surface of the public road and battered up to existing ground level over a distance of about 10 m from the road.
    b. A layer of trees shall be placed across the width of the bellmouth, overlapped by at least 1.0 m with the existing trees and extending at least 1.0 m beyond the edge of the bellmouth.
    c. A base layer of Tensar TX170 geogrid is to be placed over the surface of the trees transversely across the width of the bellmouth, extending over the width of the existing road.
    d. The road shall be built up with 500 mm of well-graded rockfill (max size = 125 mm) and then covered with a second geogrid layer of Tensar TX160 laid transversely across the full width of the bellmouth and existing road.
    e. The road shall be capped off with a further 150 mm of crushed rockfill so that the maximum thickness of rockfill is 750 mm.
3. All excavated peat and mineral soil shall be removed to a remote repository site. No temporary or permanent sidecasting shall be permitted.
4. Rockfill shall not be stockpiled on the peat or floating road during construction of the bellmouth, and any trucks travelling on the bellmouth shall only be half-filled.
5. The bellmouth shall be left for a period of 2 weeks and then traversed with the fully loaded trucks.
6. Full scale proof load tests shall be carried out on the road prior to certification for use by the cranes.
7. The cable trench shall be constructed in the peat on the north side of the floating road and shall be offset a minimum of 8.0 m from the edge of the road.

Hydrological Controls

1. Existing drainage channels across the width of the road shall be maintained with culverts to allow free flow of water under the road.

Residual Risk Mitigation Measures

1. Peat excavations shall be monitored by a geotechnical engineer.
2. Existing tension cracks along the edge of the floating road (due to compression of the adjacent peat under the road) shall be marked and monitored to determine if they are extending or widening over the course of the works.
3. A sight line of markers shall be established along the crest of the ridge on the north side of the bellmouth to observe any peat movement during construction of the bellmouth.
4. Review work practices for periods of heavy intense rainfall of 10 mm/hr, >25 mm in a 24 hour period, or >50% of monthly average in a 7 day period . Secure peat excavations in sensitive areas in advance of predicted rainfall & provide drainage to prevent back-up of surface runoff. Avoid working in sensitive areas during heavy rainfall and for up to 24 hours after, if necessary.
5. Minimise movement of machinery on the peat.
6. Ensure ancillary works are considered as part of overall peat stability assessment.
7. Plan emergency response and contingency measures.

General Geotechnical Considerations	Comments
1. No specific requirements	

L = Likelihood I = Impact R = Risk Rating (R=L X I)

WF-GRR-S8 Access Track from Public Road to T8 (Floating Road) Rev. 1 - 31/05/10

Peat Stability Risk Assessment

- Method of risk assessment compatible with general guidelines in "Managing Geotechnical Risk" by C.R.I Clayton (ICE, 2001)

Likelihood of Occurrence (L)

Hazard Likelihood		Chance per Section of Work
0	Not Applicable (<0.5 m Peat)	<1 in 1000
1	Negligible	1 in 1000 to 1 in 500
2	Low	1 in 500 to 1 in 100
3	Possible	1 in 100 to 1 in 50
4	Very Possible	1 in 50 to 1 in 10
5	Likely without appropriate mitigation measures	> 1 in 10

Impact of Occurrence (I)

Hazard Impact	Environmental Impact	Cost Impact	Time Impact
1	Very Low	<€1,000	<1 week on activity
2	Low	€1,000 - €10,000	1-4 weeks on activity, none on completion
3	Medium	€10,000 - €100,000	>4 weeks on activity, <1 week on completion.
4	High	€100,000 - €1,000,000	> 1 week on completion
5	Very High	>€1,000,000	> 10 weeks on completion

Risk Rating (R = L x I)

Likelihood (L)	Impact (I)				
	1	2	3	4	5
0	0	0	0	0	0
1	1	2	3	4	5
2	2	4	6	8	10
3	3	6	9	12	15
4	4	8	12	16	20
5	5	10	15	20	25

Risk Rating Levels and Response

Risk Rating (R = L X I)		Response
0 to 5	Trivial	Monitor
6 to 10	Tolerable	Regular Attention
11 to 15	Substantial	Early Attention
16 to 20	Intolerable	Unacceptable
21 to 25	Intolerable	Unacceptable

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Peat Stability Risk Assessment

- It is a qualitative assessment of peat stability with a semi-quantitative method of assessing the relative risk between
- There is still some judgement involved.
- The bands of Hazard Likelihood from the relative hazard rating need to be calibrated with further examples from different sites.
- The frequency of occurrence for each hazard likelihood band also needs to be calibrated to assess the actual frequency based on a database of peat failures or near misses.
- Currently it is down to the judgement of the geotechnical engineer. Perhaps there is research in this.
- Appropriate mitigation measures

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Design and Construction Mitigation Measures

Design and Construction Risk Mitigation Measures

- Micrositing of turbines and access tracks
- Method of construction of access tracks (i.e. excavate/replace or floating)
- Controls on storage of spoil
- Hydrological controls

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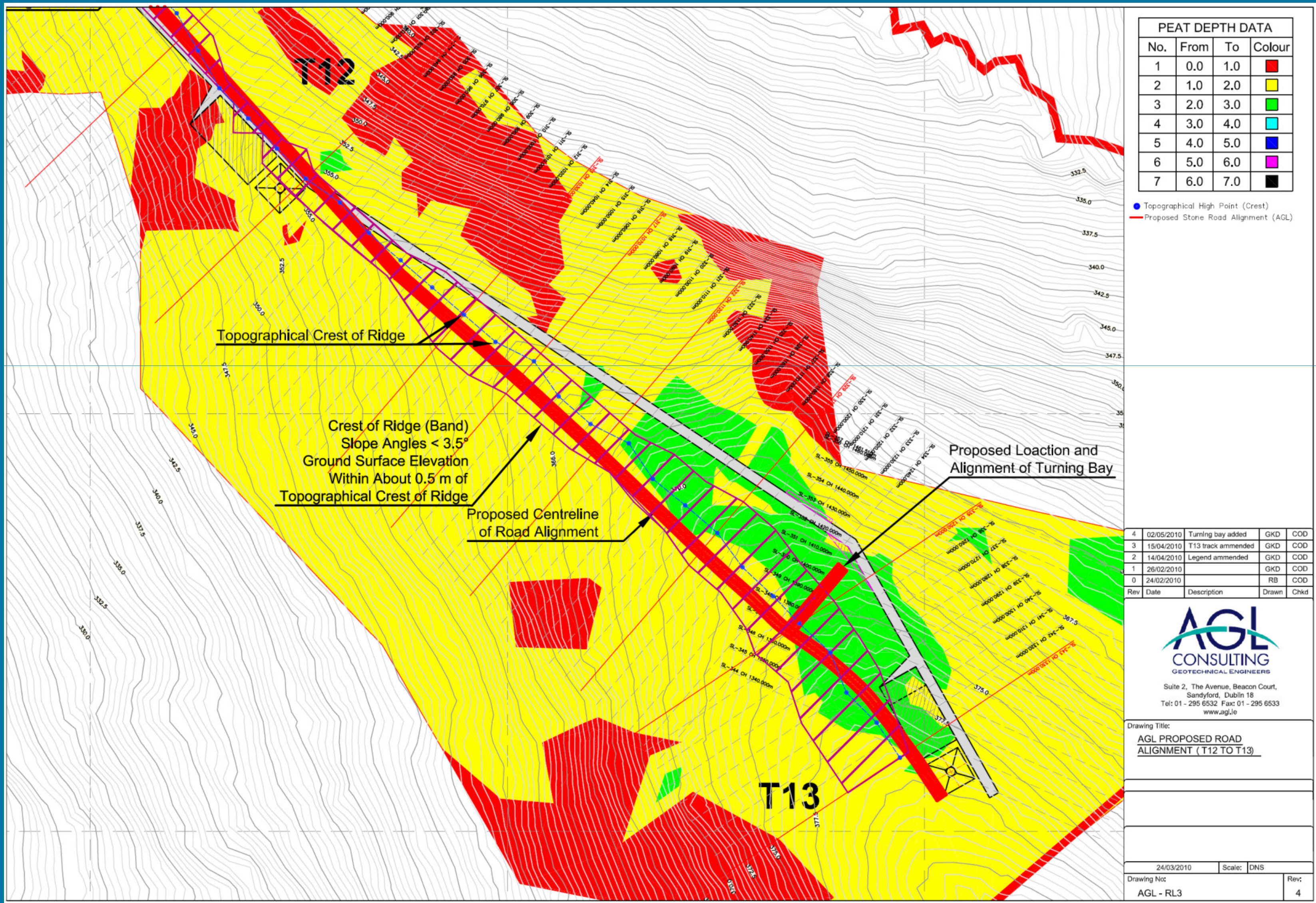
Micrositing of turbines and access tracks

Re-locate turbines and re-align access roads to areas of lower risk



Design and Construction Risk Mitigation Measures – Micrositing of turbines and access tracks

- Needs flexibility in planning constraints:
  - Allow turbine movements of up to about 50 m where possible.
  - Allow a corridor for the road alignment of up to 50 m either side of the proposed route.
- In some cases it may be necessary to obtain planning permission for an alternative route.
- Need to consider environmental constraints and land ownership.

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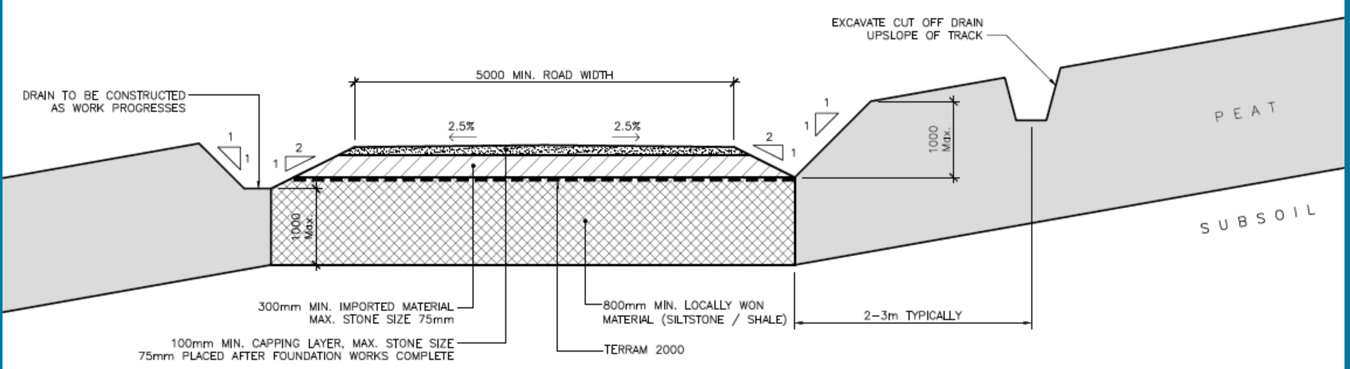
Design and Construction Risk Mitigation Measures

Method of Construction of Access Tracks:

Excavate/Replace (stone road on glacial till)

- Identify areas of shallow peat (<1.0 to 1.5 m) where road can be constructed by excavate/replace as preferred option.
- However - introduces risk of requirement for peat storage so this needs to be considered in tandem.
- Where there is a transverse slope across the road, the excavate/replace road can act as a berm to prevent a planar slide upslope from the road. Need to place fill up against peat to within 1.0 m of ground level.



TYPICAL DETAIL OF NEW ACCESS TRACK AT SLOPING CROSS SECTION
SCALE 1:50
['TYPE A1']

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Design and Construction Risk Mitigation Measures
Method of Construction of Access Tracks:
Floating Road

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Design and Construction Risk Mitigation Measures
Method of Construction of Access Tracks:
Floating Road

- Higher risk of planar slide compared to excavate/replace.
- Reduced requirement for peat disposal and stone import.
- Floating roads should be aligned along areas of shallow slopes, where possible, preferably <3ˇ.
- Not suitable for areas where there is a high risk of peat instability.
- Floating roads typically empirically designed and constructed based on experience. Analysis should be carried out in advance to design floating roads, with appropriate level of SI.

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Design and Construction Risk Mitigation Measures
Method of Construction of Access Tracks:
Floating Road – Contd.

Design Methods:

- Bearing capacity/extrusion – Unfactored c_u from Geonor-H10 65 mm x 130 mm vane give representative FoS
- Planar Sliding/Block Failure - need to check c_u at base of peat with Direct Simple Shear (DSS) tests on undisturbed piston samples, or
- Take conservative design c_u profile from Gonor H-10 profiles and assume weak layer with c_u = 2.5 kPa present at base of peat.
- Design for actual slope geometry (surface and base of peat) using:
  - Slope/W with optimised circular slip circle search for a weak layer.
  - Finite element analysis (Plaxis)

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Design and Construction Risk Mitigation Measures
Method of Construction of Access Tracks: Floating Roads – Contd.

- Recommend FoS > 1.4 using partial factor of 1.3 on live load and characteristic c_u profile without weak layer at base. Lower FoS could be accepted as worst case scenario with weak layer at base of peat.
- Other considerations:
  - Construct road directly on vegetated surface of peat.
  - Use basal layer of trees where possible.
  - Minimise thickness of granular fill to 0.5 – 0.75 m through use of geogrids with geotextile separator (Terram 2000) at base.
  - Optimum performance with two layers of geogrids – one at the base and one 150 mm from the road surface.
  - Recommend Tensar triaxial HDPE geogrids – stiffer and more robust.
  - Trial sections can be constructed to optimise design.

Design and Construction Risk Mitigation Measures- Control of Spoil

- Possible methods of storing peat in order of increasing risk:
  - Borrow pit
  - Bunded repository
  - Upslope from a stone road
  - Floating repository.
- Level of risk should be reflected in level of analysis and investigation.
- Recommend all excess mineral soil to be removed to a borrow pit.

Design and Construction Risk Mitigation Measures- Control of Spoil – Borrow Pit/Bunded Repository

Peat is fully contained below ground in the borrow pit and above ground by rockfill berms.

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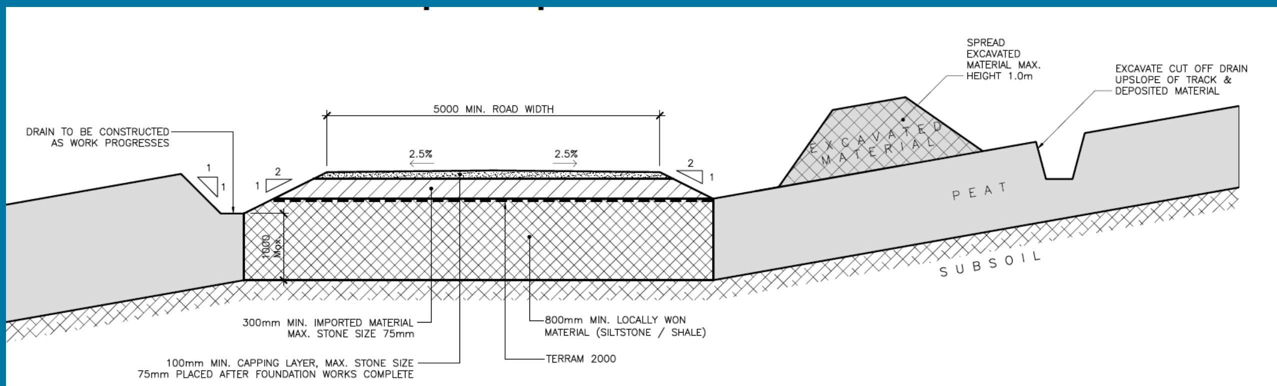
Design and Construction Risk Mitigation Measures- Control of Spoil – Peat Upslope from Stone Road

Road acts as a berm to prevent planar slide on transverse slope.

Shallow longitudinal slope (<3).

Depth of peat is limited by slope angle to prevent flow slide in remoulded peat:

- 1.0 m for < 5.0°
- 0.75 m for 5.0 ° – 7.5°
- (0.5 m for 7.5 ° to 10.0°)



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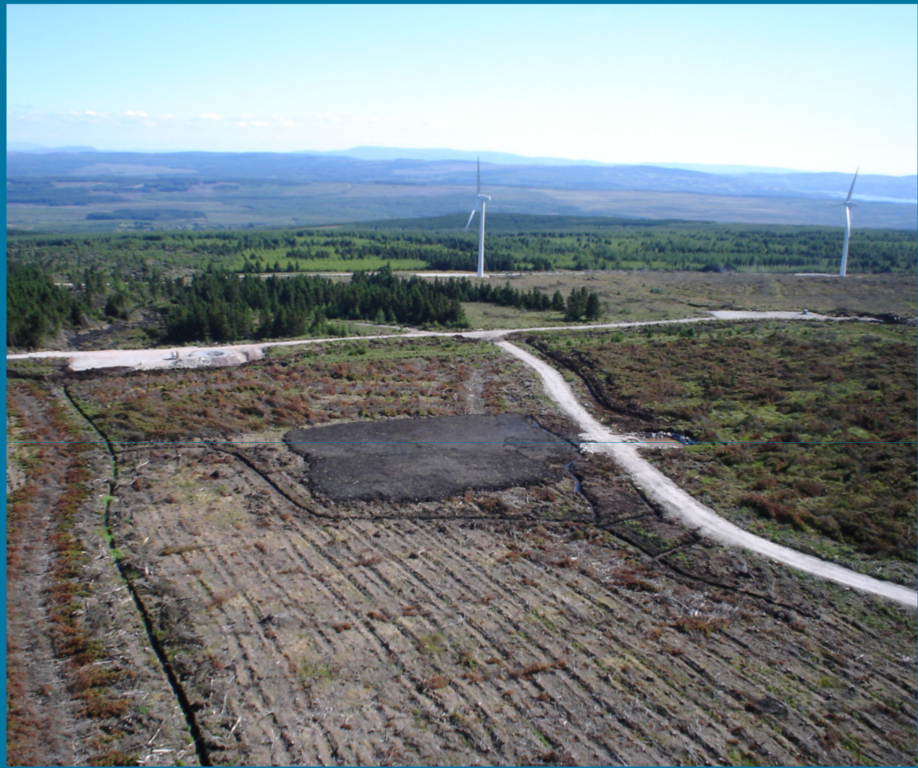
Design and Construction Risk Mitigation Measures- Control of Spoil – Floating Peat Repositories



Derrybrien Windfarm – Floating peat repositories restricted to 1.0 m of peat on slopes <3° (ground surface and base of peat) and out of high risk areas.

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Design and Construction Risk Mitigation Measures- Control of Spoil – Floating Peat Repositories

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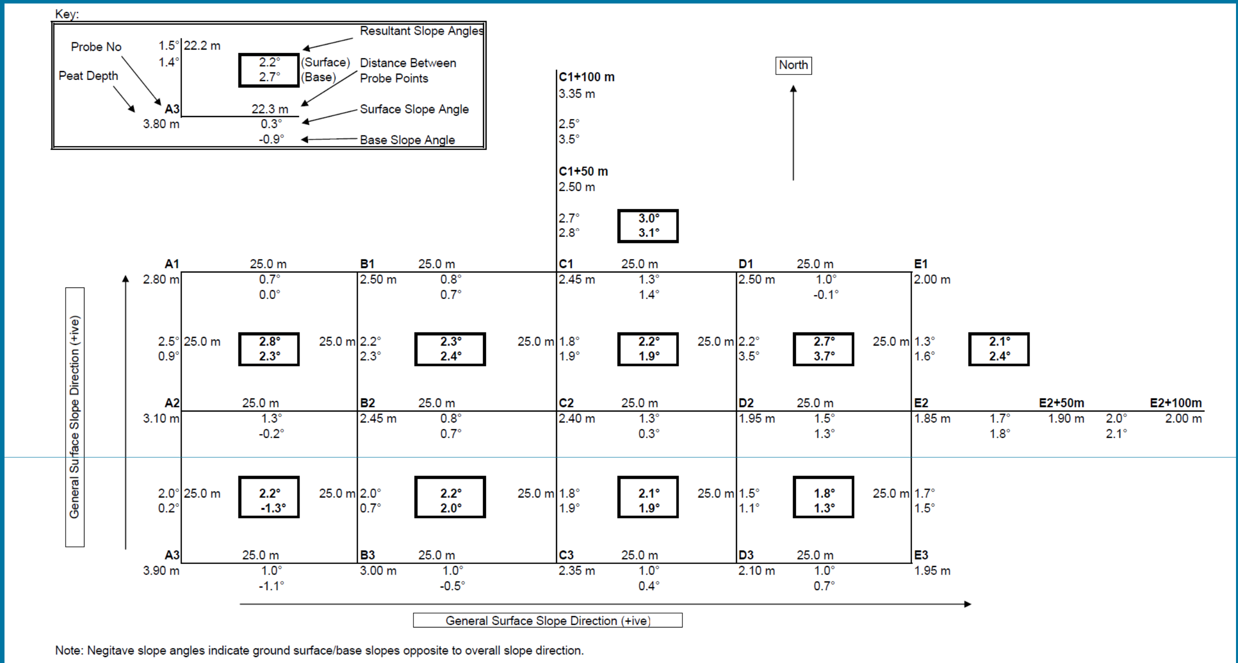
General Guidelines for "Floating" Peat Repositories (Infinite Slope Analysis)

c_u = 5kPa | Partial Factor on Deposited Peat = 1.3 | Min FoS = 1.5

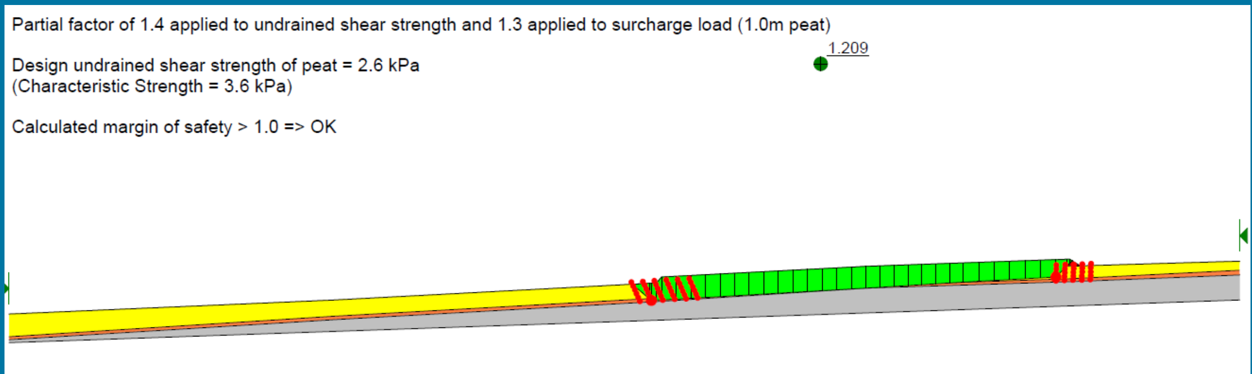
Slope Angle	Peat Thickness 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	Max Depth of Deposited Peat
0.5	30.3	23.7	19.5	16.5	14.4	12.7	11.4	10.3	9.4	8.7	1.0 m
1.0	15.2	11.9	9.7	8.3	7.2	6.3	5.7	5.1	4.7	4.3	
1.5	10.1	7.9	6.5	5.5	4.8	4.2	3.8	3.4	3.1	2.9	
2.0	7.6	5.9	4.9	4.1	3.6	3.2	2.8	2.6	2.4	2.2	
2.5	6.1	4.7	3.9	3.3	2.9	2.5	2.3	2.1	1.9	1.7	
3.0	5.1	4.0	3.2	2.8	2.4	2.1	1.9	1.7	1.6	1.4	
3.5	4.3	3.4	2.8	2.4	2.1	1.8	1.6	1.5	1.3	1.2	
4.0	3.8	3.0	2.4	2.1	1.8	1.6	1.4	1.3	1.2	1.1	
4.5	3.4	2.6	2.2	1.8	1.6	1.4	1.3	1.1	1.0		
5.0	3.0	2.4	2.0	1.7	1.4	1.3	1.1	1.0			
5.5	4.3	3.0	2.3	1.9	1.6	1.4	1.2	1.1			0.5 m
6.0	4.0	2.8	2.1	1.7	1.4	1.2	1.1				
6.5	3.7	2.5	2.0	1.6	1.3	1.2	1.0				
7.0	3.4	2.4	1.8	1.5	1.2	1.1					
7.5	3.2	2.2	1.7	1.4	1.2	1.0					
8.0	3.0	2.1	1.6	1.3	1.1						
8.5	2.8	2.0	1.5	1.2	1.0						
9.0	2.6	1.8	1.4	1.1							
9.5	2.5	1.7	1.3	1.1							
10.0	2.4	1.7	1.3	1.0							

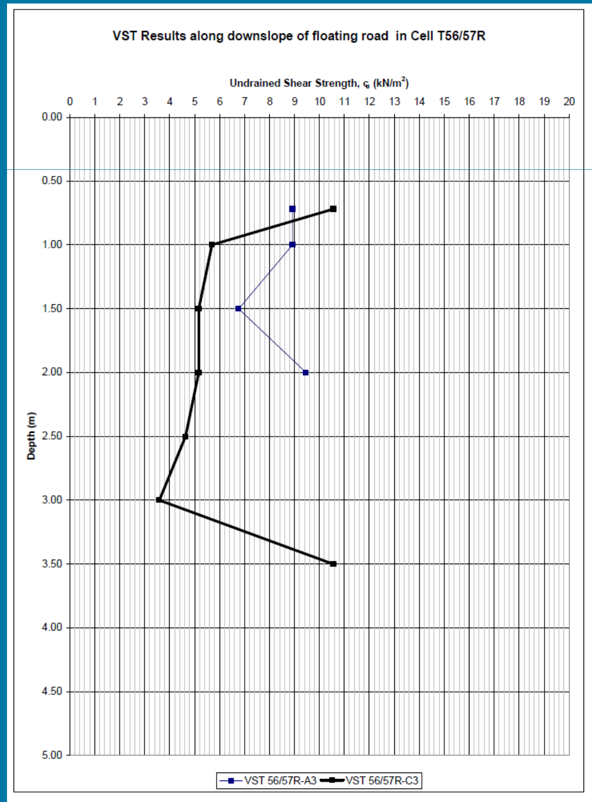
- Recommend conservative approach with FoS > 2.0 as this would account for weak layer of c_u = 2.5 kPa at base of peat.
- Need to check actual topography at base of peat along representative sections.
- Avoid high risk areas e.g. Convex breaks in slope directly upslope from a defined watercourse.

Design and Construction Risk Mitigation Measures- Control of Spoil – Floating Peat Repositories



For more detailed assessment carry out site-specific analysis assuming weak layer of c_u = 2.5 kPa at base of peat.





Design and Construction Risk Mitigation Measures- Hydrological Controls

- Preserve or improve existing drainage on site.
- Provide permanent outfalls for granular fill in stone roads and crane hardstandings to prevent a build up of groundwater within the fill.
- Construct impermeable “plugs” at regular intervals along long sections of roads sloping in one direction to divert water within the fill to controlled outfalls.
- Hydrological controls are sometimes at-odds with environmental constraints, which tend to limit drainage.

Construction Control Measures

Construction Control Measures

- Review of Contractor's method statements
- Construction monitoring
- Testing and certification of floating roads
- Rainfall monitoring with work restrictions during and after periods of heavy or sustained rainfall.
- Effective planning of emergency control measures

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Construction Control Measures – Review of Contractor's Method Statements

- Geotechnical review of contractor's method statements to ensure peat stability control or mitigation measures will be implemented.
- Review should include method statements from all ancillary works on the site that could have an impact on peat stability, including sub-contractors (e.g. Cable-trenching, transmission line pole erection etc.)
- Consider certification/permit to work scheme to ensure that work does not proceed without geotechnical review.

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Construction Control Measures: Construction Monitoring

- Periodic or full-time monitoring by a geotechnical engineer.
- Keep daily records of peat excavations
  - Date/Weather/Location
  - Peat/Subsoil Conditions (peat depth/subsoil type/discontinuities)
  - Hydrology (Surface water, drains, watercourses)
  - Hydrogeology (groundwater ingress/piping/seepage at base)
  - Stability of peat excavations (stable/spalling/squeezing/collapse)
  - Mitigation measures implemented (backfilling/controlled displacement of peat/drainage)
- Periodic site audits by a senior geotechnical engineer

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Construction Control Measures: Testing and Certification of Floating Roads

- Serviceability testing
  - Observe fully-loaded 4-axle truck (36 tonnes) travelling at low speeds (10 kph) along road.
  - Measure road deflection at selected locations under empty, half-filled and full-loaded truck.
  - Classify road and identify areas requiring remedial work (e.g. additional geogrid and capping layer)

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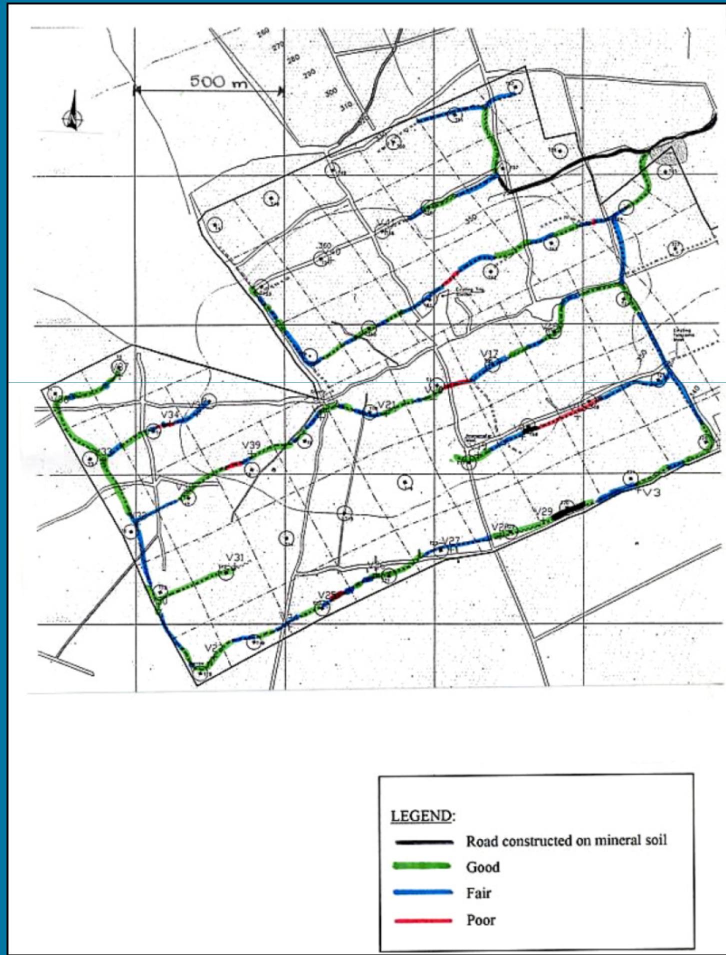
Construction Control Measures: Testing and Certification of Floating Roads

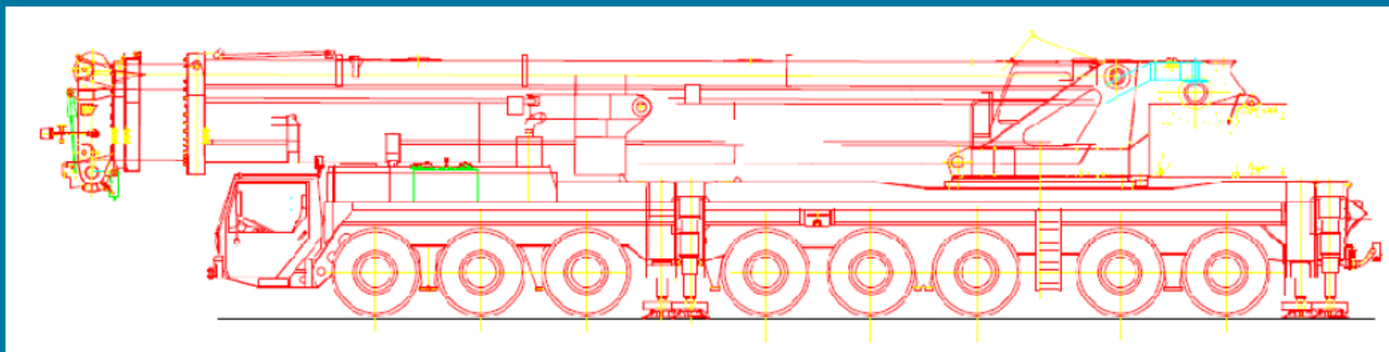
Road Performance Classification	Performance Criteria (36t total load 8-10t axle load)
Good	➢ Road deflections generally <10 mm ➢ Road deflects relatively rigidly under truck load with only slightly greater deformation locally under the wheel load at localized soft spots. ➢ Road surface is even with minor rutting and no loose rockfill.
Fair	➢ Road deflections between 10 and 30 mm ➢ Road deflects noticeably under wheel loads ➢ Road surface is relatively even with some rutting along the line of the wheels. The rockfill is generally dense. ➢ Local transverse rutting occurs at soft spots where the rockfill has loosened over weak peat, or where there are gaps in the basal reinforcement trees.
Poor	➢ Road deflections are greater than 30 mm (up to about 60 mm) ➢ Road deforms very noticeably under wheel loads in wave-like motion. ➢ Deformations are uneven causing the truck to tilt slightly on local soft spots. ➢ Road surface is in poor condition with both longitudinal and transverse rutting creating an uneven road surface. ➢ Rockfill is loosened over worst areas.



Developed from testing > 15 kM of floating roads on Derrybrien Windfarm

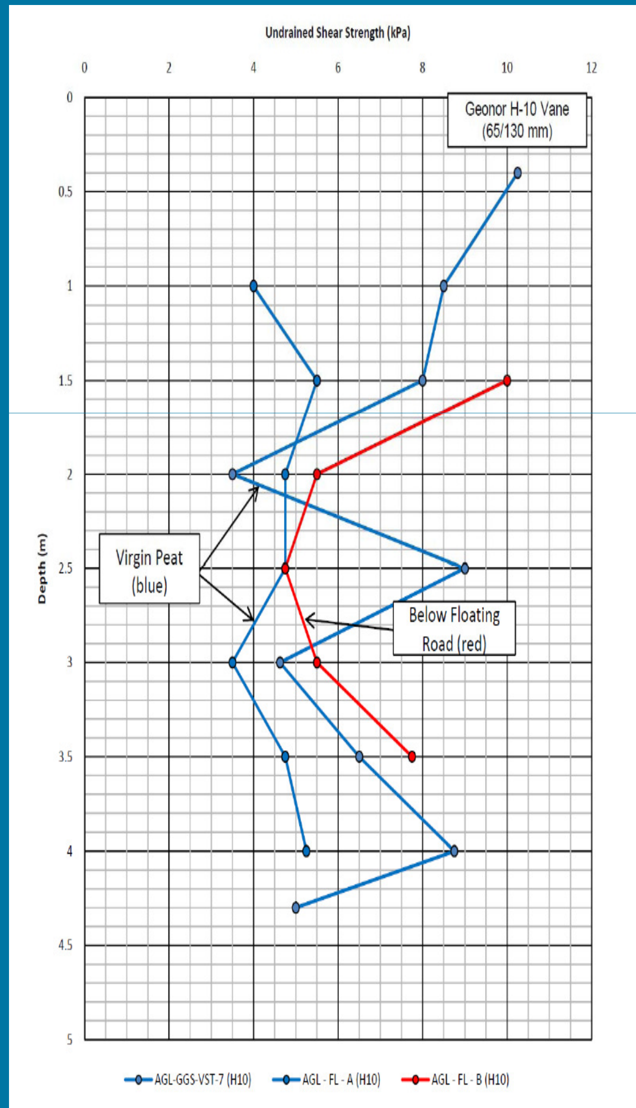
Construction Control Measures: Testing and Certification of Floating Roads

- Full-scale proof load testing:
  - Determine maximum load – usually travelling weight of crane (25 kPa over 3.5 m width).
  - Incrementally load the road to maximum load (or 1.3 x maximum load) using live load (e.g. 36-tonne trucks or Volvo A-40s) or dead load (e.g. granular fill)
  - Area of loading should match proposed load where possible.
  - Tested road can be certified

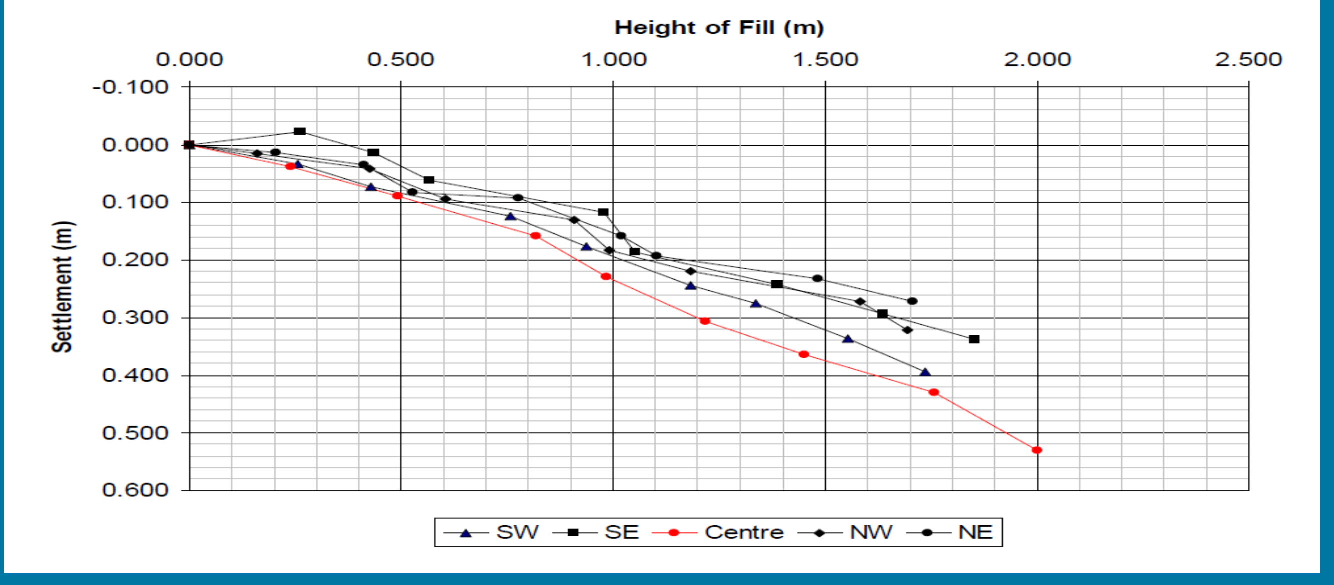


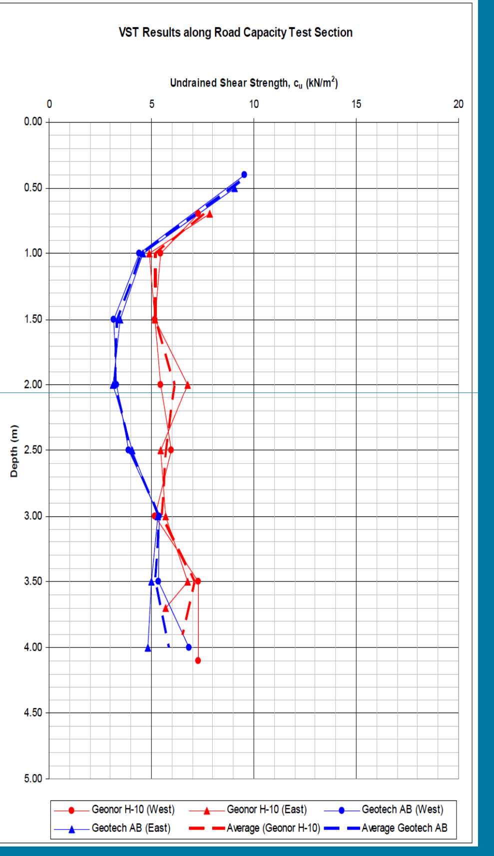
Vehicle Nature:
Mobile Crane
Reg. No: 04 D 501
Weight: 108 Tonnes
Overall Lenght: 21m
Overall Width: 3.0m
Overall Height: 4m
No. of Axles: 8
Weight on No.1 Axle: 13.5
Weight on No.2 Axle: 13.5
Weight on No.3 Axle: 13.5
Weight on No.4 Axle: 13.5
Weight on No.5 Axle: 13.5
Weight on No.6 Axle: 13.5
Weight on No.7 Axle: 13.5
Weight on No.8 Axle: 13.5
Dist. between Axle 1 & 2: 1.65m
Dist. between Axle 2 & 3: 1.65m
Dist. between Axle 3 & 4: 2.8m
Dist. between Axle 4 & 5: 1.65m
Dist. between Axle 5 & 6: 1.65m
Dist. between Axle 6 & 7: 2.25m
Dist. between Axle 7 & 8: 1.65m
No. of wheels per Axle: 2
Des. of Wheels and Tyres:
All Terrain Singles 16.00 R 25

Construction Control Measures: Testing and Certification of Floating Roads



Construction Control Measures:
Testing and Certification of Floating Roads





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Construction Control Measures:

Rainfall monitoring:

- Daily on-site rainfall monitoring
- Review work practices for periods of intense, heavy or sustained rainfall e.g.
  - >10 mm/hr,
  - >25 mm in a 24 hour period, or
  - >50% of monthly average in a 7 day period.
- Secure peat excavations in sensitive areas in advance of predicted rainfall & provide drainage to prevent back-up of surface runoff.
- Avoid working in sensitive areas during heavy rainfall and for up to 24 hours after, if necessary.

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Construction Control Measures:

Emergency Procedures:

- Plan emergency procedures for a peat slide at the outset of a project.
- Health & safety – notification and evacuation procedures, escape routes & assembly points (site staff and local residents).
- Limit environmental impact –
  - Indentify main watercourses flowing off site and categorise by importance.
  - Identify suitable locations for barrages, sedimentation ponds and silt traps.
  - Stockpile materials on site.
  - Plan emergency procedures to mobilise and allocate resources.

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Peat Stability -
An Integrated Approach to Risk Management

- Designer's Peat Stability Risk Assessment
- Design and Construction Mitigation Measures
- Construction Control Measures