CIVL2410 Soil Mechanics 1

THE UNIVERSITY OF SYDNEY · LEVEL 2 · SEMESTER 2, 2026

Full guide + ask Sia about CIVL2410

SIDE 1/2 DEFINITIONS → FORMULAS → DECISIONS → CHECKS

EXAM REVISION SHEET

Final Exam: 40% · 2 h · hurdle task

0 · Exam map

COURSE.JSON · BRIEF

Computing | Mid-sem 20 | Practical 20 | Final Exam 40

COMPONENT	WEIGHT	FORMAT / STATUS
Lab Safety Quiz	0%	Week 1 · 5 min
Computing assignment	20%	Week 6 · 4-page report
Mid semester quiz	20%	1.5 h · confirm week
Practical exam	20%	Week 13 · 2 h group
Final Exam	**40%**	2 h · **hurdle**

Permitted materials: not confirmed for this offering in the course materials we hold — check the exam instructions on the LMS. *BRIEF.md; course.json*

The final must be passed in its own right. Core competence is the gate: first secure phase relations, effective stress and flow-net reading; then connect seepage → stress → settlement → strength.

phase + classify → head + seepage → effective stress → settlement + strength

Answer chain: measured state → water → grain-skeleton stress → behaviour.

FINAL HABIT *Sketch first; declare datum, water table, drainage condition and drainage path before selecting a relation.*

1 · Three decisions

COURSE STUDY STRATEGY

IF THE STEM ASKS…	DECIDE BEFORE ARITHMETIC
Pore pressure	Static hydrostatic head or moving-water flow net?
Strength / deformation	Drained or undrained for this loading rate?
Consolidation time	One-way or two-way drainage?

CORE-RECALL GATE

PROMPT	RECITE AND CHECK
Describe a soil state	Draw phases; name each numerator and denominator; distinguish volume saturation from mass moisture content.
Classify	0.075 mm route first; 4.75 mm and fines for coarse soil, A-line and LL=50 for fine soil.
Move water	One datum; h=u/γw+z; direction follows total head; state Darcy assumptions.
Read seepage	Boundary conditions → orthogonal curvilinear squares → spaces Nf, Nh → Q, u, uplift, exit FS.

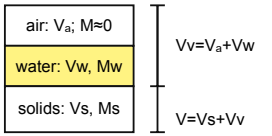
1 sketch + datum → 2 choose branch → 3 show units → 4 check physics

Every quantitative answer: sketch, branch, units, independent physical check.

2 · Phase relations

CH 1

ONE SOIL · THREE PHASES



Redrawn phase block: every packing, water and weight ratio comes from these boxes.

PACKING + WATER

```
e = Vv/Vs   n = Vv/V = e/(1+e)
S = Vw/Vv   m = Mw/Ms   eS = mGs
```

UNIT WEIGHTS · ΓW = 9.81 KN/M³

```
γ = (Gs + Se)γw/(1+e)
γd = Gsγw/(1+e)
γsat = (Gs+e)γw/(1+e)
γ′ = γsat-γw
```

TARGET	USE	DO NOT
Total stress below WT	γsat	γ′
Effective stress below WT	σ−u or γ′ shortcut	subtract u after γ′
Travel time	seepage velocity	Darcy velocity

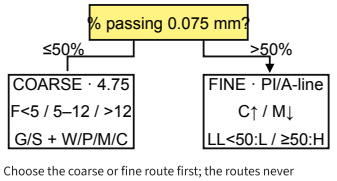
Relative density Id=(emax−e)/(emax−emin). ***Void ratio*** has fixed Vs beneath it, so Δe measures compression cleanly; porosity's total-volume denominator changes.

CHECK *Soil unit weights should be roughly 12–22 kN/m³. An outside value signals arithmetic, not a novel material.*

3 · Grading → USCS

CH 2–4

```
Cu=D60/D10   Cc=D30²/(D60D10)
PI=LL-PL   LI=(w-PL)/PI
A-line: PIA=0.73(LL-20)
```



Choose the coarse or fine route first; the routes never recombine.

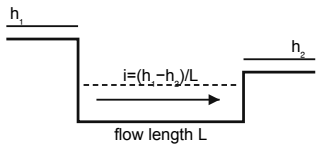
CHECK	RULE
Well graded	gravel Cu>4; sand Cu>6; both 1<Cc<3
Curve reading	close mass balance; interpolate log diameter
Meaning	symbol predicts behaviour; it does not replace measured k, strength or compressibility

FINE-SOIL INDICES

INDEX	QUESTION ANSWERED	READ
PI=LL−PL	How wide is the plastic range?	<7 low; >17 high

6 · Head + Darcy

CH 5–6



Water follows decreasing total head, not necessarily decreasing pressure.

HEADS + FLOW

```
h = u/γw + z   i = Δh/L
q = kiA   v = q/A = ki
vs = v/n   travel time = path/vs
```

Declare one datum and measure every z and total head from it. Velocity head is negligible at soil seepage velocities. Darcy assumes steady, saturated, laminar flow through homogeneous soil with constant k; high-gradient coarse flow is the first common failure.

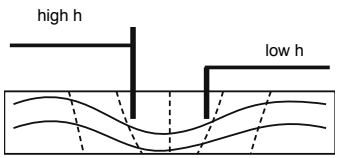
LABORATORY PERMEABILITY

```
constant: k = QL/(Aht)
falling: k = (aL/At) ln(h1/h2)
```

Falling head suits a fine soil because a small discharged volume produces a readable level change. Report k with method, stress level, saturation and specimen direction.

7 · Flow-net rules

CH 7–8



Flow lines and equipotentials cross at 90°; cells approximate curvilinear squares.

```
∂²h/∂x² + ∂²h/∂z² = 0
Q = kH(Nf/Nh) per unit width
Δh per drop = H/Nh
```

Count spaces, not lines. Every channel carries equal discharge; every equipotential interval loses equal head. The net shape depends on geometry and boundaries, not k, for homogeneous isotropic soil.

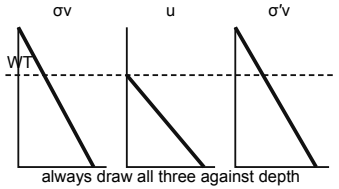
READ FROM NET	RELATION
Total head at P	upstream head − counted drops
Pore pressure	u = γw(hP−zP)
Exit gradient	iexit = Δh / last-cell length
Critical gradient	ic = γ′/γw; FS = ic/iexit

CONSTRUCTION + EXTENSIONS

Fix constant-head and impermeable boundaries first. Draw the two curve families at right angles, refine until circles fit the cells, then count spaces. A finer mesh cannot repair wrong boundaries.

8 · Effective stress

CH 10

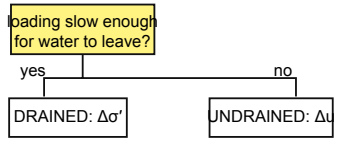


Total stress, pore pressure and effective stress must share one depth scale.

TERZAGHI

```
σ′ = σ - u
σv = surcharge + ΣγiHi
static u = γw(depth below WT)
```

Total stress counts solids and water. Pore water pushes but cannot resist shear. Effective stress carried by the grain skeleton controls compression, distortion and shearing resistance. At σ′=0 the grains lose contact: quicksand, piping and liquefaction are the same limit reached by different routes.



Drainage is a loading-rate decision, not a permanent label attached to a soil.

LOADING	IMMEDIATE RESPONSE	USE
Drained	water leaves; Δσ′ develops	effective stresses/parameters
Undrained saturated clay	Δu carries load; little Δσ′	total stress + su

STRESS-PROFILE CONSEQUENCES

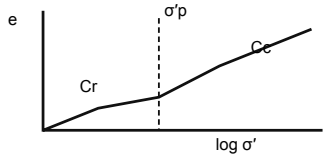
CHANGE	Σ	u	Σ′ / BEHAVIOUR
Lower static WT; soil remains saturated	little change	falls	rises → compression / settlement
Rapid load on clay	rises	rises initially	little immediate rise
Upward seepage	same overburden	above hydrostatic	falls; zero at boiling
Capillary zone	overburden	negative	greater than total stress

σ fixed u rises → σ′=σ−u falls to 0 → no grain contact

Quicksand, piping and liquefaction share the same σ′=0 limit.

9 · Settlement magnitude

CH 11–12



e–log σ′: shallow recompression to σ′p, steep virgin compression beyond it.

STRESS HISTORY FIRST

```
OCR = σ′p/σ′0
σ′f = σ′0 + Δσ′
if σ′f≤σ′p: Δe=Cr log10(σ′f/σ′0)
if crossed: Δe=Cr log10(σ′p/σ′0)+Cc
log10(σ′f/σ′p)
s = HΔe/(1+e0)
```

Compare σ′0, σ′p and σ′f before choosing one slope or two. For several layers, evaluate stress change at each layer centre and sum settlements; do not average nonlinear parameters.

GEOMETRY	ANALYSIS	SETTLEMENT
Wide load; no lateral strain	1-D oedometer	compression / consolidation
Local footing; lateral movement	elastic half-space stress bulb	immediate + consolidation

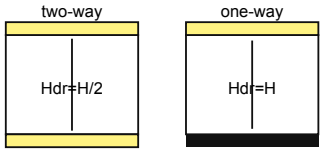
IMMEDIATE SETTLEMENT BY SUBLAYERS

```
si ≈ Σ(Δσzi Hi / Eui)
keep Δσ in same units as Eu
```

Elastic stress distribution depends on load geometry; the modulus controls calculated strain and carries greater uncertainty. Immediate and consolidation settlements are added, not alternatives.

10 · Consolidation rate

CH 13



The drainage path, not the nominal layer thickness, enters the time factor.

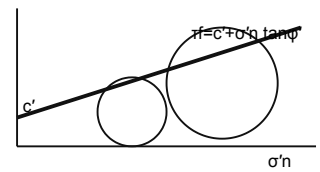
```
Tv = cvt/Hdr²   U = function(Tv)
cv = k/(mvγw)   k = cvmvγw
at same U and same clay: t ∝ Hdr²
```

Magnitude comes from compression and stress history; rate comes from cv, drainage path and time. Compute separately, then settlement at time t = U × final primary settlement. Terzaghi theory does not predict secondary compression.

PARAMETER	DEFINITION / USE
mv	volumetric strain per Δσ′ over a stated range; secant, not constant
cv	rate parameter combining k and compressibility

11 · Shear strength

CH 14

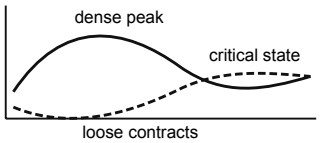


Mohr–Coulomb is an empirical local straight-line fit, not a universal material constant.

```
drained: τf = c′ + σ′n tanφ′
undrained saturated clay: τf = su; φu≈0
Nφ = (1+sinφ′)/(1-sinφ′)
c′=0 triaxial: σ′1 = Nφσ′3
```

CASE	STRESS / PARAMETERS	MEANING
Drained	σ′; c′, φ′	fundamental skeleton response
Undrained	σ; su	condition-specific shortcut
Large movement	critical-state φ′	peak dilatancy already spent

Subtracting u shifts a Mohr circle left without changing its radius: principal stress difference is the same in total and effective stresses. Always label primes before starting algebra.



At equal mean effective stress, dense and loose starts converge at large strain.

12 · Where parameters come from

CH 15

METHOD	DELIVERS	CANNOT DELIVER
Disturbed sample	grading, limits, classification	natural strength / consolidation
Undisturbed sample	strength, compressibility, cv	perfectly unchanged fabric
SPT	N profile + empirical checks	precise design modulus
CPT	continuous qc, fs, u	material for laboratory tests
Geophysics	wide qualitative anomalies	most direct design parameters

desktop + geophysics → CPT profile → targeted boreholes

Use wide coverage to target expensive holes, then recover material for needed tests.

Semester 2 formal examination period, from 16 November 2026 (the Exams Office publishes the exact date).
Check your exam instructions on the LMS for what you may bring; use this sheet to revise and self-test.

CIVL2410 Soil Mechanics 1 · Worked self-test drills

ANSWER PATH · JUDGEMENT CARDS · CLASSIC TRAPS · EXAM-MORNING PLAN

Full guide + ask Sia about CIVL2410

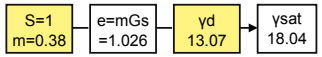
SIDE 2/2 FIVE WORKED DRILLS · METHOD CHOOSER · IF-X-THEN-Y · TRAPS

SELF-TEST FIRST

Cover the answers; say the branch decision before the formula

W1 · Phase block CH 1 WORKED

Given: saturated clay, Gs=2.70, moisture content m=38%. Find e, γd, γsat and γ'.



The saturated condition unlocks the bridge relation before any unit weight.

1. S=1 ⇒ e=mGs=0.38×2.70=**1.026**.
2. γd=2.70×9.81/(1+1.026)=**13.07 kN/m³**.
3. γsat=(2.70+1.026)×9.81/2.026=**18.04 kN/m³**.
4. γ'=18.04−9.81=**8.23 kN/m³**.
5. Independent check: γsat=γd(1+m)=13.07×1.38=18.04.

TRAP *Saturation is a volume ratio; moisture content is a mass ratio. They meet only through eS=mGs.*

Classification sprint CH 2–4

68% pass → fine	PI=52−22 =30	A-line 23.4	above + H → CH

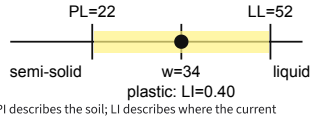
Source values: 68% finer than 0.075 mm, LL=52%, PL=22% ⇒ CH.

If instead classifying the 500 g sand example: D60=0.635 mm, D30=0.300 mm, D10=0.126 mm ⇒ Cu=5.0 and Cc=1.1. Curvature passes but sand needs Cu>6, so it is **poorly graded**.

CLASSIC ERROR	REPAIR
linear D interpolation	interpolate log diameter
grading coefficients for fine soil	stop after 0.075 mm split
PI alone decides C/M	compare PI with A-line at that LL

Limits mini-drill CH 3 WORKED

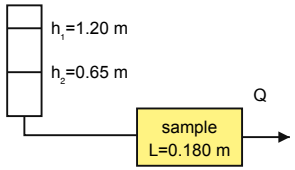
Given: LL=52%, PL=22%, natural w=34%; 28% finer than 2 μm. PI=52−22=**30**, so high plasticity. LI=(34−22)/30=**0.40**, inside the plastic range: firm and mouldable rather than liquid. Activity=30/28=**1.07**, in the normal band.



PI describes the soil; LI describes where the current specimen sits.

W2 · Falling head CH 6 WORKED

Given: specimen d=75 mm, L=180 mm; standpipe d=8 mm; h falls 1.20→0.65 m in 12 min.



A narrow standpipe converts a tiny flow volume into a readable head fall.

1. A=π(0.075)²/4=**4.418×10⁻³ m²**.
2. a=π(0.008)²/4=**5.03×10⁻⁵ m²**; a/A≈1/88.
3. t=12×60=**720 s**.
4. aL/(At)=5.03×10⁻⁵×0.180/(4.418×10⁻³×720)=2.84×10⁻⁶.
5. ln(1.20/0.65)=0.613; therefore k=**1.7×10⁻⁶ m/s**, consistent with fine/silty sand.

CHECKS *Square the diameters through area; convert mm and minutes before substitution; h_1/h_2 must exceed 1 so ln is positive.*

Darcy judgement cards CH 5–6

IF YOU SEE X	DO Y
Two piezometer levels	flow from higher total head
"quantity / discharge"	q=kiA using gross area
"arrival / travel time"	vs=ki/n, then distance/vs
Fine soil; tiny discharge	falling head, not constant head
Field-scale defects / layers	prefer field test; lab specimen may miss them

Darcy v=ki uses total area — seepage vs=v/n actual pore speed

Quantity uses Darcy velocity; time of flight uses the faster pore-space velocity.

Reservoir speed check CH 5 WORKED

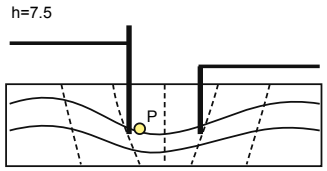
Given: horizontal sand, thickness 1.2 m, width 8 m, length 25 m; upstream/downstream heads 4.6/2.8 m; k=3.5×10⁻⁴ m/s; n=0.38.

1. Δh=1.8 m; i=1.8/25=**0.072**.
2. A=1.2×8=**9.6 m²**.
3. q=kiA=3.5×10⁻⁴×0.072×9.6=**2.42×10⁻⁴ m³/s ≈0.24 L/s**.
4. Darcy v=ki=2.52×10⁻⁶ m/s, but travel needs vs=v/n=**6.63×10⁻⁶ m/s**.
5. t=25/vs≈3.8×10⁶ s=**4.4 days**.

SANITY CHECK	EXPECTED
Head direction	4.6→2.8; positive chosen i
Velocity order	vs>v because n<1

W3 · Flow net all the way COURSE WORKED

Given: k=5.0×10⁻⁵ m/s; 5 flow lines; 10 equipotentials; H=3.6 m. Upstream head=7.5 m above datum. P is on third equipotential, zP=2.4 m. Last drop spans 0.50 m; γsat=20.0 kN/m³.

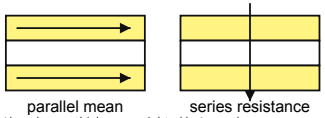


Five flow lines ⇒ four channels; ten equipotentials ⇒ nine drops.

1. Nf=4; Nh=9. Q=kH(Nf/Nh)=5.0×10⁻⁶×3.6×4/9=**8.0×10⁻⁶ m³/s per m**.
2. Each drop Δh=3.6/9=**0.40 m**. At P: hP=7.5−3×0.40=**6.30 m**.
3. Pressure head=6.30−2.40=3.90 m; uP=9.81×3.90=**38.3 kPa**.
4. Exit gradient iexit=0.40/0.50=**0.80**.
5. γ'=20.0−9.81=10.19; ic=10.19/9.81=1.04; FS=1.04/0.80=**1.30**.

INTERPRET *Piping is local: use the last cell, not average H over the whole path. Once erosion begins, the path shortens and the mechanism accelerates.*

Layered-flow chooser CH 9



Along layers: thickness-weighted k. Across layers: harmonic k, controlled by the tight seam.

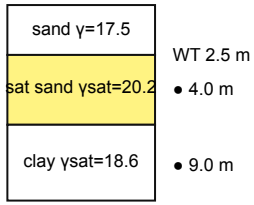
```
kǁ = Σ(kiHi)/ΣHi   k⊥ = ΣHi/Σ(Hi/ki)
source profile: kI=5.8×10⁻⁵;
k⊥=6.0×10⁻⁷ m/s
```

For 2.0 m sand at 1×10⁻⁴, 1.0 m clay at 1×10⁻⁷ and 3.0 m silty sand at 5×10⁻⁵ m/s: ΣkiHi=3.50×10⁻⁴, so kI=3.50×10⁻⁴/6=**5.8×10⁻⁵**. Across layers, ΣHi/ki=1.008×10⁷, so k⊥=6/1.008×10⁷=**6.0×10⁻⁷ m/s**. The clay supplies about 99% of the perpendicular resistance.

STEM DIRECTION	MODEL	DOMINANT FEATURE
Toe drain; along bedding	parallel conductances	open layer carries flow
Leakage through liner	series resistances	tight seam controls
Anisotropic homogeneous soil	transformed section	scale then geometric mean

W4 · Stress → settlement CH 10–11 WORKED

Stress profile: 2.5 m sand at 17.5 kN/m³; saturated sand to 6 m at 20.2; saturated clay to 10 m at 18.6. WT at 2.5 m.



Use layer thicknesses for σ; use depth below WT for u.

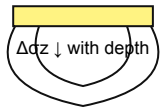
DEPTH	Σv	u	Σ'v
4.0 m	2.5×17.5+1.5×20.2=74.1	1.5×9.81=14.7	**59.4 kPa**
9.0 m	43.75+3.5×20.2+3×18.6=170.3	6.5×9.81=63.8	**106.5 kPa**

Then settlement: H=4.0 m, e0=0.80, Cr=0.05, Cc=0.30, σ'0=80 kPa, σ'p=140 kPa, Δσ'=120 ⇒ σ'f=200 kPa, so cross the memory.

1. Δer=0.05 log10(140/80)=**0.0122**.
2. Δev=0.30 log10(200/140)=**0.0465**.
3. Δe=0.0587; s=0.0587×4/1.80=**0.130 m = 130 mm**.

TRAP *One average slope across the corner is wrong. Compare the three stresses before selecting the equation.*

Immediate response CH 12



A local load spreads; analyse sublayers only through the meaningful influence depth.

Given: three 2.0 m sublayers; Δσz=48, 30, 18 kPa; Eu=12, 15, 20 MPa. Convert moduli to 12,000, 15,000, 20,000 kPa before dividing.

LAYER	ΔΣZH/EU	SI
Top	48×2/12000	8.0 mm
Middle	30×2/15000	4.0 mm
Bottom	18×2/20000	1.8 mm
Total immediate		**13.8 mm**

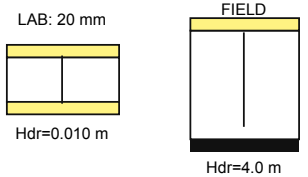
The top contributes 58% because stress increase is largest near the load and the layer is softest. Add immediate settlement to consolidation settlement; do not choose between them.

ELASTIC-SOLUTION CHOOSER

LOADED SHAPE	USE / MOVE
Point, line, strip, circle	matching integrated Boussinesq case
Rectangle	corner solution + superposition

W5 · Consolidation clock CH 13 WORKED

Given: a 20 mm oedometer specimen drains both faces and reaches U=50% in 9 min. Same clay in field: 4.0 m layer, upward drainage only. Find time to U=50%.



Same U and same clay cancel Tv and cv; only drainage-path scaling remains.

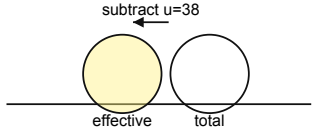
1. Two-way lab path=20/2=**10 mm=0.010 m**.
2. One-way field path=**4.0 m**.
3. tfield/tlab=(4.0/0.010)²=400²=1.6×10⁵.
4. tfield=9×1.6×10⁵=**1.44×10⁶ min ≈1000 days ≈2.7 years**.

Halving a path quarters time. Vertical drains work by shortening the path; preloading advances settlement before construction and leaves the clay overconsolidated.

SAY IT *U is a fraction of final primary settlement, not a settlement magnitude. Secondary compression continues after excess pore pressure has dissipated.*

Strength drill card CH 14 WORKED

UU test: su=24 kPa; c'=0; ϕ'=28°; u at failure=38 kPa. Radius is unchanged by subtracting u, so σ'1−σ'3=2su=48 kPa. Nϕ=(1+sin28)/(1−sin28)=2.77. Thus (2.77−1)σ'3=48 ⇒ σ'3=27.1 kPa; total cell pressure= 27.1+38=65 kPa .



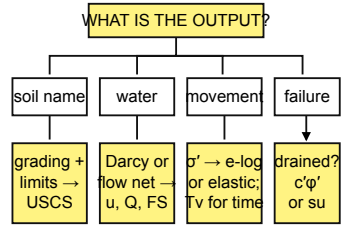
Subtracting pore pressure shifts the circle without changing radius or deviator stress.

TRAP *Never feed total σ into c',φ' or effective σ' into su without a justified conversion.*

Loading-stage cards CH 13–14

STAGE / TEST	WHAT CHANGES / USE
Consolidation t=0→end	Δu≈Δσ, then u dissipates as σ' rises; U(Tv) gives fraction
UU	no drainage in either stage; condition-specific su
CU	drain in consolidation; undrained shear with u measured
Drained	drain throughout; obtain c',ϕ' directly

13 · Method chooser ALL CHAPTERS



Name the desired output, then make the branch decision that selects the relation.

IF YOU SEE X	DO Y IMMEDIATELY
Water table + layers	draw σ, u, σ' on one depth axis
Dam / wall seepage	declare datum; read h from flow net
Exit boiling	local iexit versus ic; report FS
σ'f crosses σ'p	split Cr then Cc stages
Settlement "when?"	separate magnitude from U(Tv)
Short-term saturated clay	total stress + su
Need strength / cv	undisturbed sample at drilling

14 · Classic traps CHAPTER TIPS

- Double buoyancy: using γ' and subtracting u again.
- Wrong datum: total head and elevation from different references.
- Lines not spaces: five flow lines do not mean Nf=5.
- Average gradient: misses the last-cell piping risk.
- Wrong path: layer thickness substituted for Hdr.
- Prime drift: c',ϕ' paired with total stress.
- False precision: empirical SPT modulus treated as design truth.

SPT + site card CH 15 WORKED

150 mm seating: 4 blows — discard
150 mm: 7 blows
150 mm: 11 blows

N = 7 + 11 = 18

SPT N is the last two 150 mm intervals, never all three.

N=18 lies in the 10–30 band, so the sand is medium dense. The source correlation gives drained modulus ≈(2600–2900)N=**47–52 MPa**. Report it as an order-of-magnitude check: empirical scatter and unknown delivered hammer energy make it unsuitable as a precise settlement modulus.

Exam-morning plan COURSE STRATEGY

1. Confirm date, time, venue and current materials instructions on the LMS.
2. Recite: static/seeping; drained/undrained; one-/two-way drainage.

Semester 2 formal examination period, from 16 November 2026 (the Exams Office publishes the exact date).
Check your exam instructions on the LMS for what you may bring; use this sheet to revise and self-test.