<u>Liquefiability</u> evaluations also in need of info on Stress History / Aging

- Jamiolkowski et al. (S. Francisco 1985) "*Reliable predictions of sand liquefiability...require…some new in situ device [other than CPT or SPT], more sensitive to effects of past* ***STRESS-STRAIN HISTORIES***"
- Leon et al. (ASCE GGE 2006) South Carolina sands. "*Ignoring* ***AGING*** *and evaluating CRR from in situ tests insensitive to aging (SPT, CPT, VS) underestimated CRR by a large 60 %*"
- Monaco & Schmertmann (ASCE GGE 2007) "*Disregarding* ***AGING*** $\approx$ *omitting a primary parameter in the correlation predicting CRR*"

Ignoring Stress History ≈ omit a primary parameter. Consequence : CRR predicted by CPT (insensitive to SH) uncertain

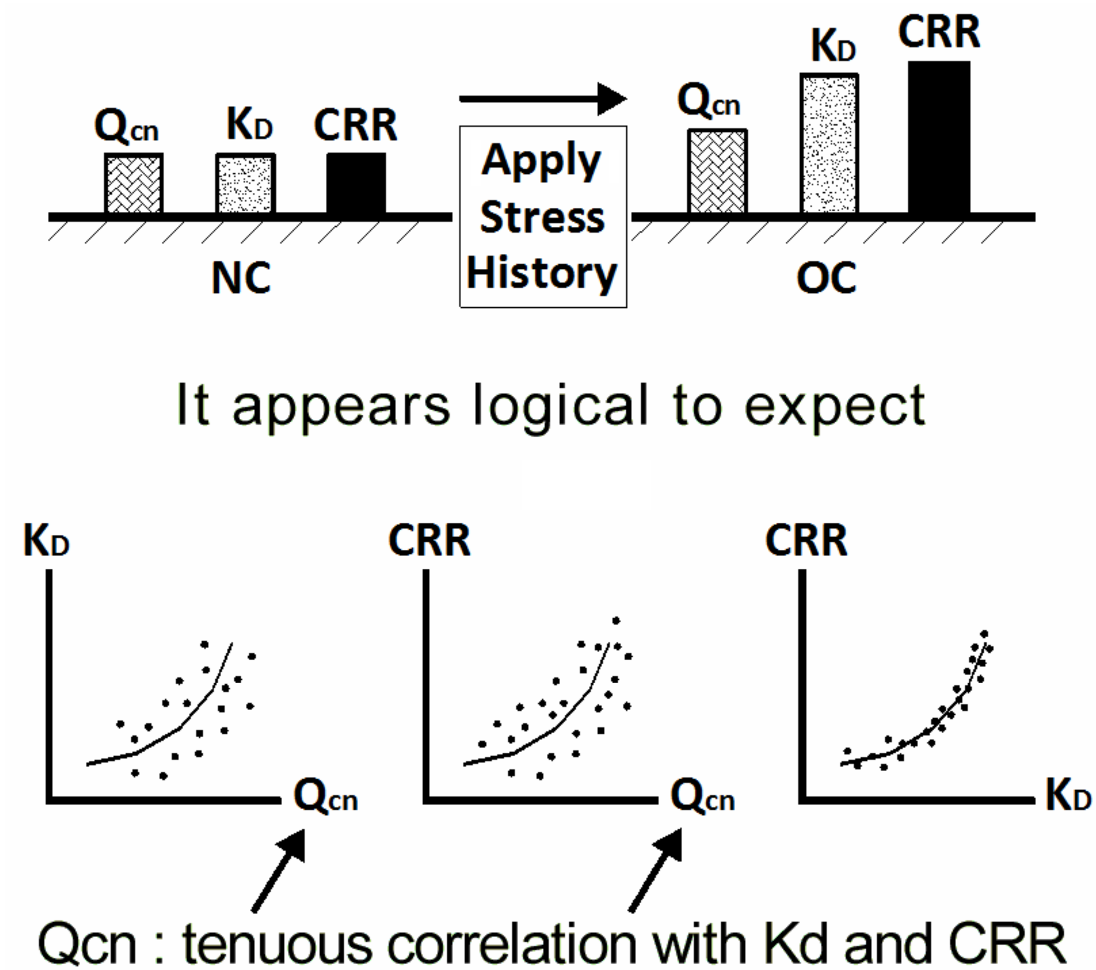
This is the reason why v. cautious recommendations on CRR by CPT :

Robertson & Wride (1998) ➡ CRR by CPT adequate for low-risk projects. For high-risk : estimate CRR by more than one method

Youd & Idriss 2001 (NCEER Workshops) ➡ use 2 or more tests for a more reliable evaluation of CRR

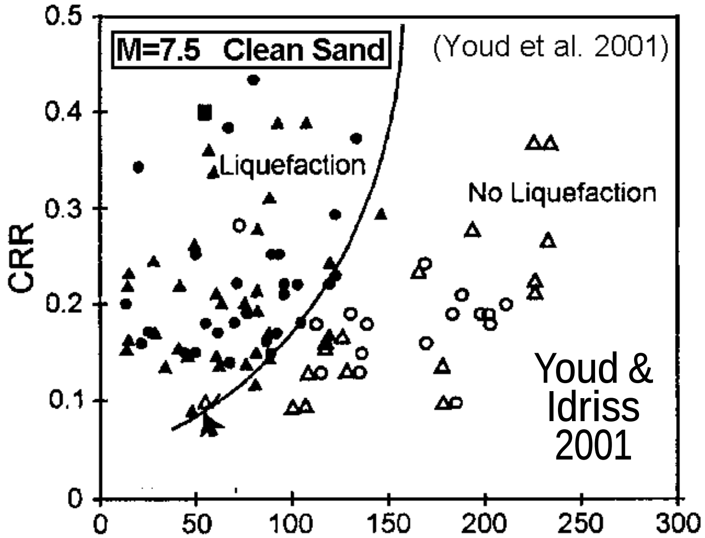
Idriss & Boulanger (2004) ➡ the allure of relying on a single approach (e.g. CPT-only) should be avoided

Why expect a stricter correlation and a more accurate CRR if CRR is predicted by Kd



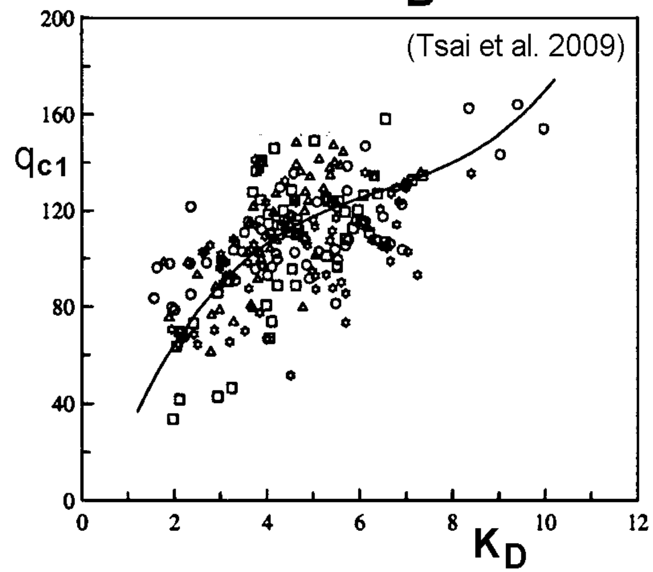
OK DMT is more sensitive to SH. But there is much more experience for CPT. Therefore Tsai translated the large CPT experimental base to DMT.

CONSENSUS q_{c1}- CRR for CPT



$q_{c1} = q_c/\sigma'_{vo}$

q_{c1}- K_D



↑

$q_{c1} = f(Kd)$

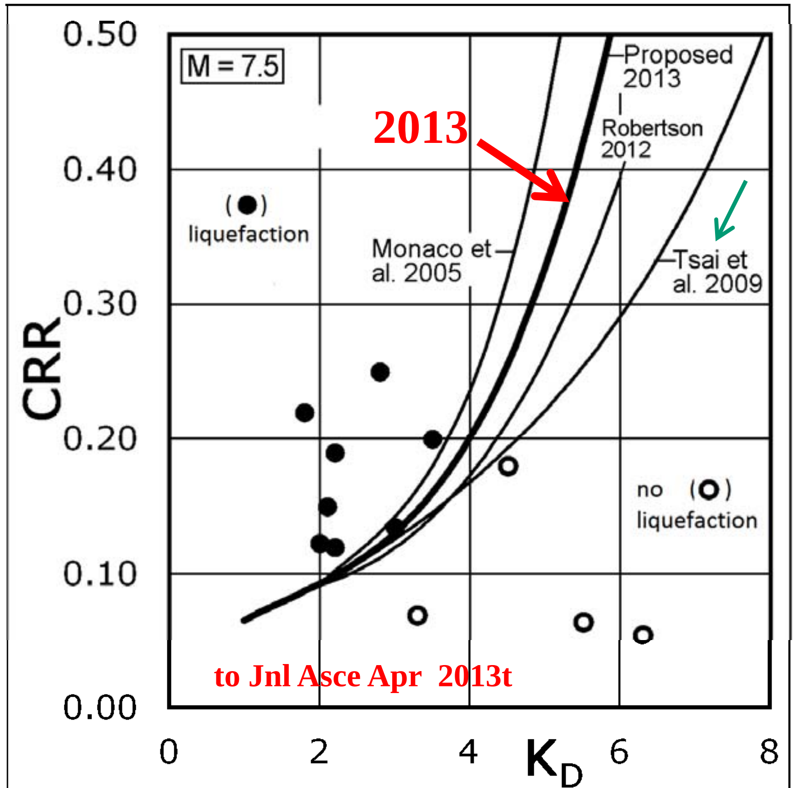
Replace q_{c1} with Kd
Thus : obtain CRR-Kd

Tsai (2009) ran side-by-side CPT-DMT. From profiles-CPT next to profiles-DMT he had pairs (Qc1, Kd) $\Rightarrow$ Qc1=f(Kd)

Tsai's 2009

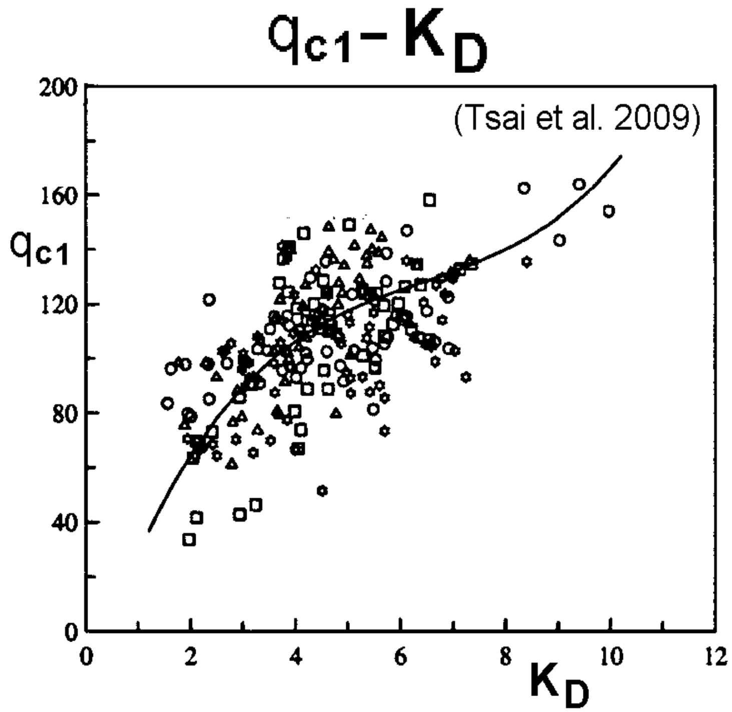
and

latest (2013) correlations to predict CRR from Kd



Monaco et al 2005	$0.0107\ K_D^3 - 0.0741\ K_D^2 + 0.2169\ K_D - 0.1306$
Tsai et al. 2009	$\exp\left[\left(\frac{K_D}{8.8}\right)^3 - \left(\frac{K_D}{6.5}\right)^2 + \left(\frac{K_D}{2.5}\right) - 3.1\right]$
Robertson 2012	$93\,(0.025\ K_D)^3 + 0.08$
Proposed 2013	$0.0038\ K_D^3 - 0.0176\ K_D^2 + 0.0532\ K_D + 0.0264$

Scatter of the Qc1-Kd relation

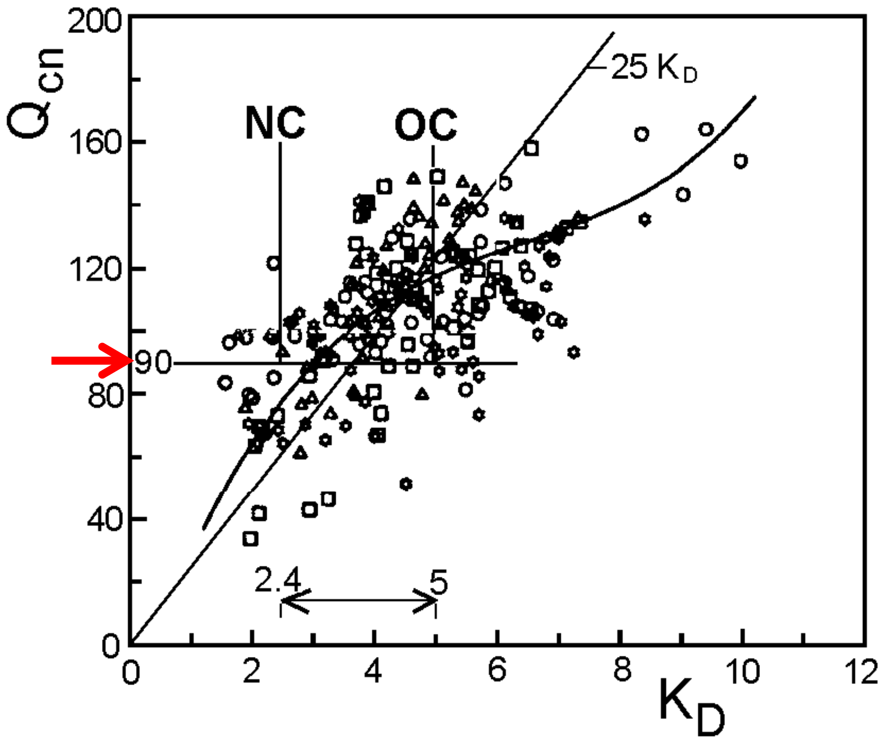


A notable feature of the Qc-Kd correlation (used for the translation) is the high scatter.

At first sight one might consider doubtful the resulting Kd-CRR correlation, being the translation based on the highly dispersed Qc1-Kd correlation.

Not so. The scatter is just natural, is the consequence of Kd reacting to factors unfelt by Qc1. If there was no scatter would mean Qc1 and Kd contain the same information, which is not the case, as Kd is reactive to SH, Qc1 is not.

Consider two sites identical except one has had SH. Qcn is the same, but Kd is higher in site with SH.



Eg we might find the same Qcn= 90 in sands having :

Kd=2.4 (≈ liq → CRR=0.12)
or
Kd=5 (no liq → CRR=0.22)

In conclusion while Qcn=90 predicts CRR = 0.15, CRR could in reality be 0.12-0.22 (factor 2). Note : 0.12-0.22 are both right ! explains historical controversies by researchers.

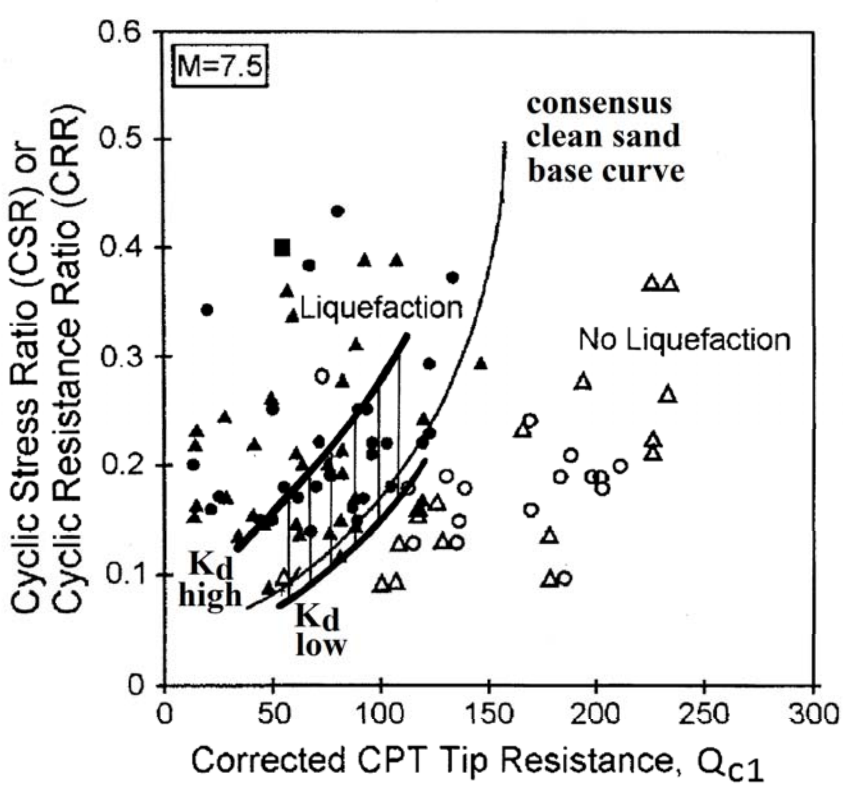
High scatter in Kd-Qcn is good news

The higher the scatter, the higher the possible accuracy gain in predicting CRR by moving from predicting CRR based on parameters scarcely sensitive to Stress History to predicting CRR based on K_D >>sensitive to Stress History.

Translation via average eliminates scatter. The translation is ave to ave. Then low/ high Kd will automatically assign low/ high CRR, though Qc may be the same.

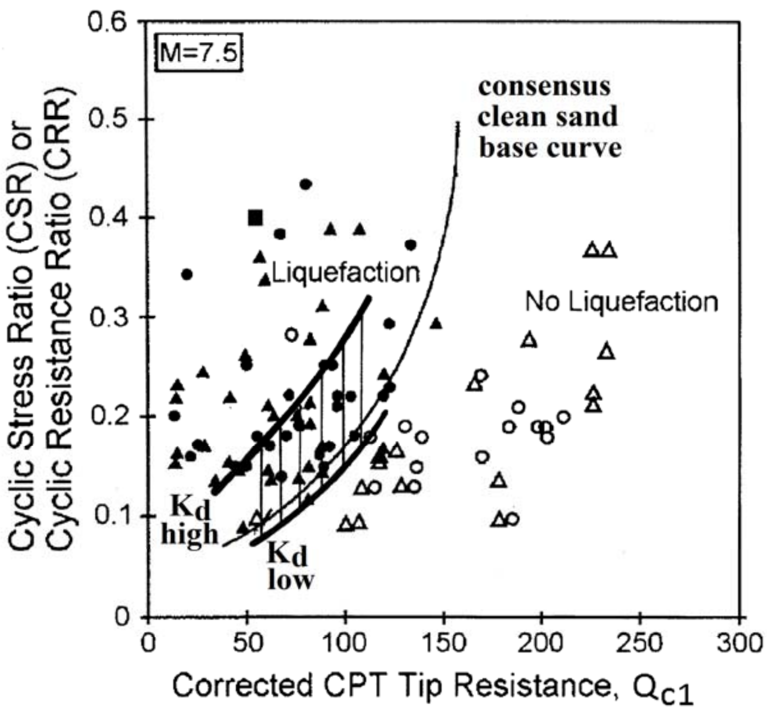
Recent research confirmed : the CPT-clean-sand curve <u>not unique</u> but comprised in a <u>wide</u> band f(SH)

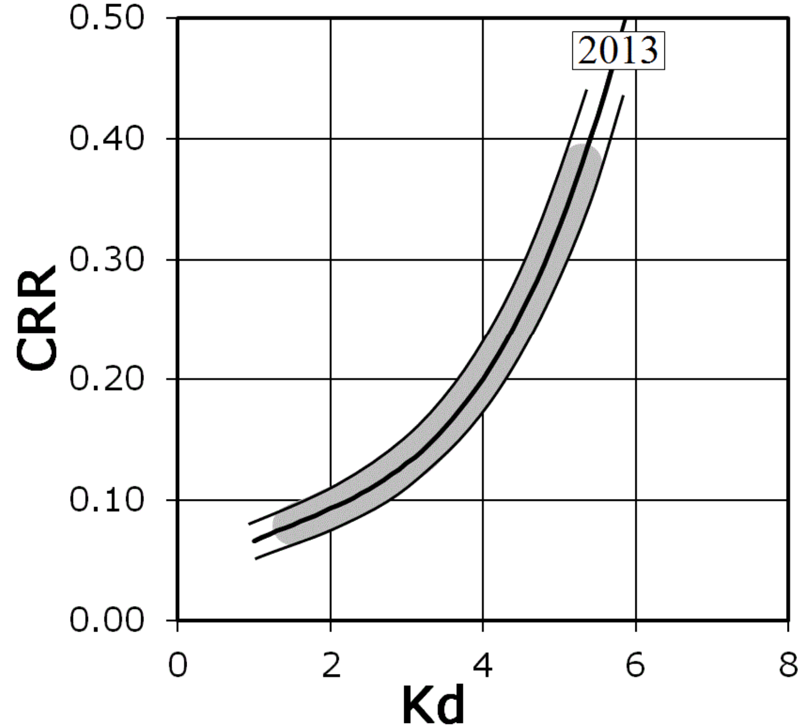
This Fig. too : for a given Qc → highly variable CRR by CPT
Lower limit to be adopted for sites with SH and viceversa.
The CPT "consensus" curve is generally conservative.
BUT can be v. uneconomical in prestressed/ aged sands.



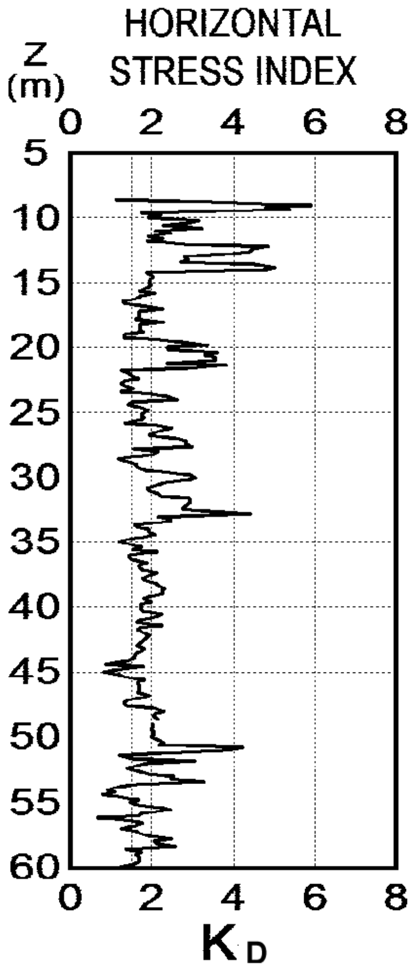
Coincides with Lewis 1999 :
"*using <u>CPT current correlations</u> in old/ aged sands will, at best, result in v. conservative and uneconomical design, at worst in v. costly remedial measures or cancellation of a project*"

The 2013 CRR-Kd correlation is expected to reduce band of uncertainty for predicting CRR



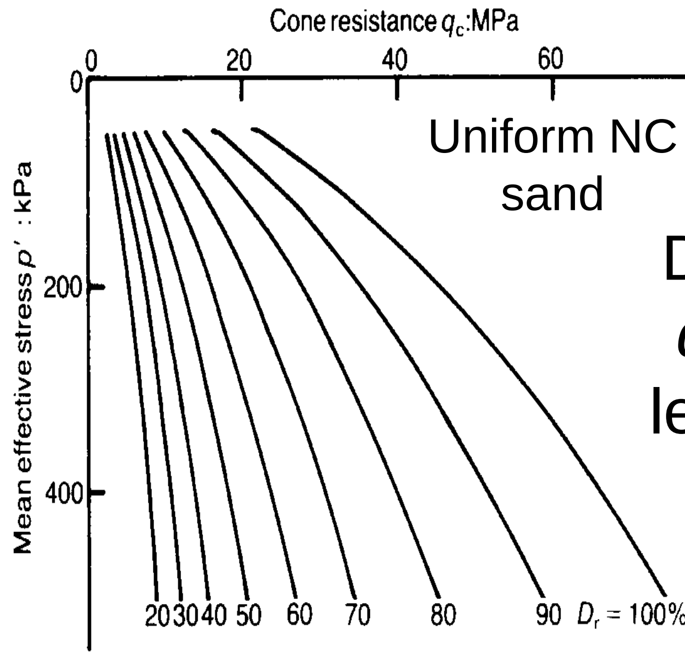


A note on exponent *n* used for obtaining the normalized parameters Kd or Qcn (used for predicting CRR)



Blade no arching **:**
side ratio ≈6

$$Q_{cn} = [(q_c - \sigma_v)/\, p_a]\, (p_a/\sigma'_v)^n$$

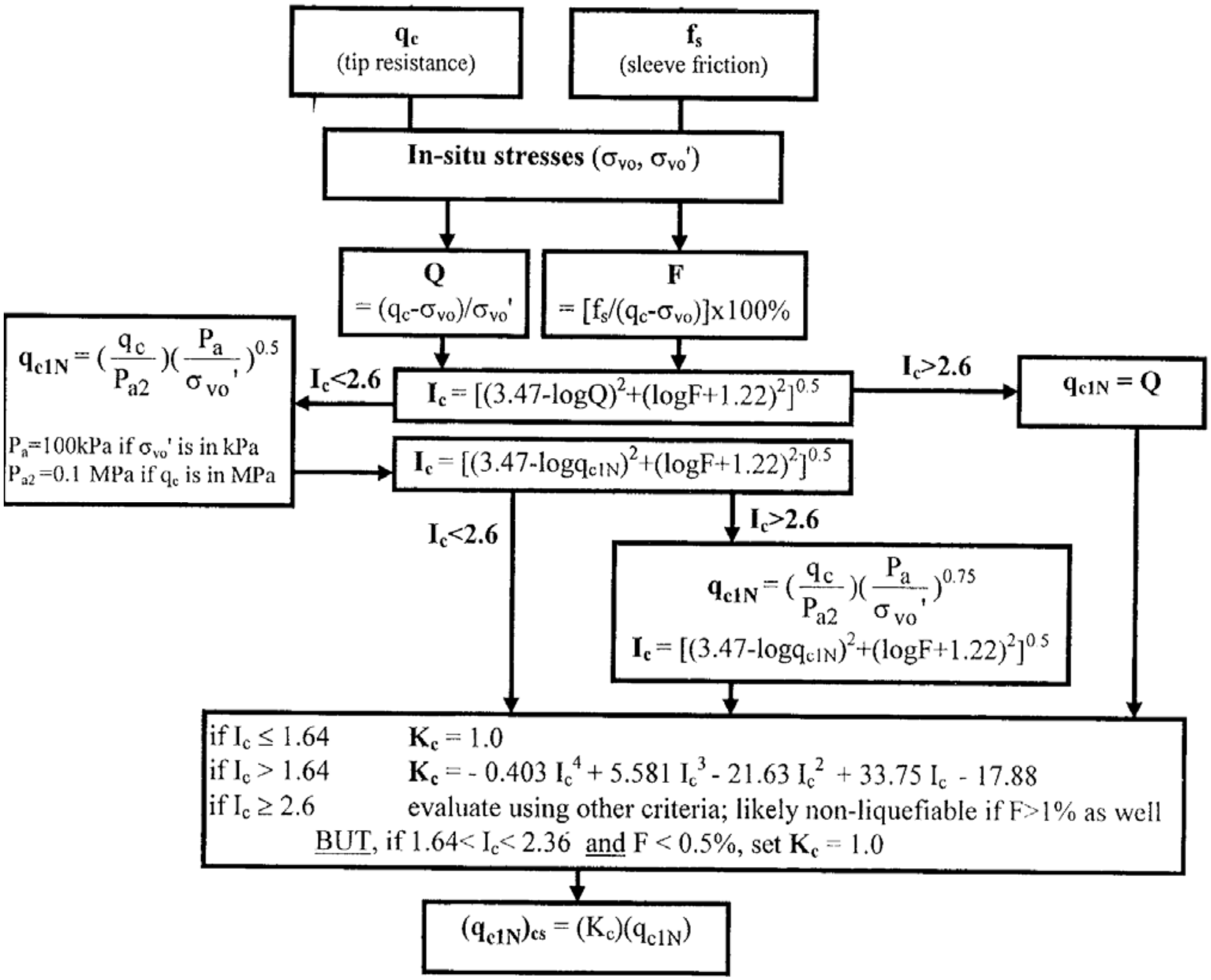


Uniform NC sand

Due to arching :
$q_c(z)$ *increases*
less than linearly

n = 1 a welcome simplification – avoids the iterative procedure to determine Q_{cn} and *n*, an additional soil unknown (*n*=0.5-1)

Determining "*n*" (0.5 to 1) not straightforward
Flow chart - Iterations by computer



Robertson & Wride – Canad.G.J. 1998