*International workshop on the soil element test*
*for liquefaction analysis (Pre-LEAP-ASIA-2019 workshop event)*

# Application of liquefaction test for performance-based seismic design practice

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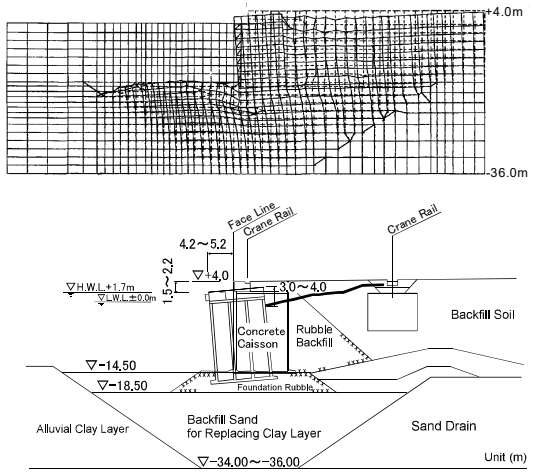
Our study started from the experience of severe damage to structures Mainly due to Liquefaction

Since the shaking (ground motion) is so strong,
we need to admit that
it is difficult to be 'No damage'.

We should permit the occurrence of a certain kind/level of damage to some structures.

But we need to be able to explain,
why we can permit the damage.

We need to know what will happen.
We need to know the performance of the structure




FEM can work very well

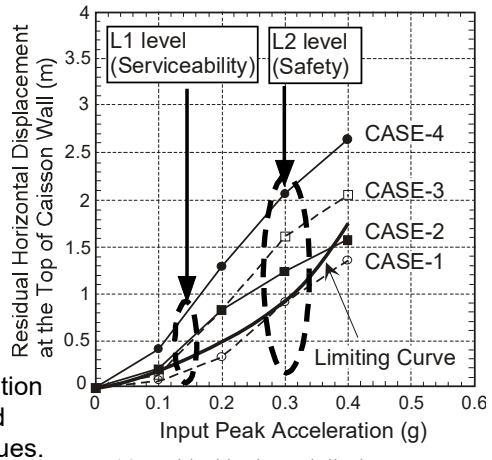
FEM result

Observation

## FEM is good enough for design practice

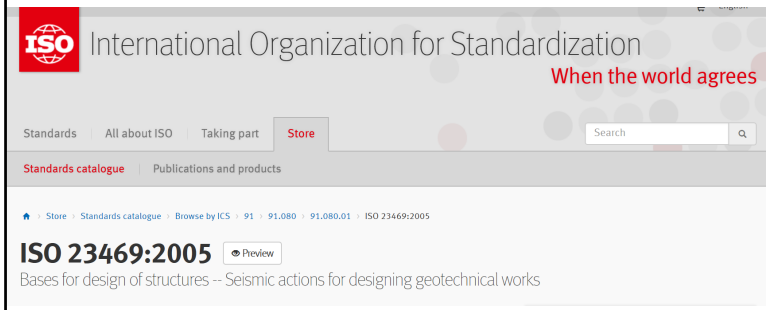
So, PBD
is now utilized
in practice.

Anticipated deformation
should be compared
with permissible values.




(a) Residual horizontal displacement

## This idea of PBD is now integrated in ISO23469




However, we still have many issues to be considered.

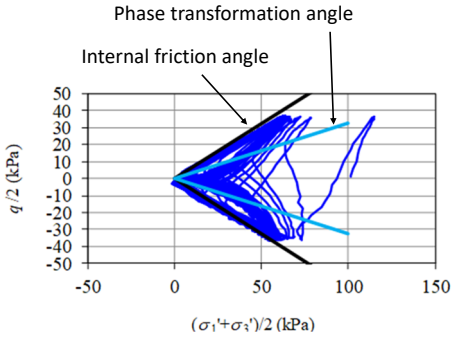
Validation & Verification of the codes => LEAP !

But the validation depends on parameters.

## How we determined the parameters.
## Example : physical parameters in FLIP

| Type | Paramters | | |
|---|---|---|---|
| Physical property | $\rho_t$ | Density | Laboratory test of in-situ sample |
| | n | porosity | |
| Dynamic property | $\sigma_{ma}'$ | Effective confining stress for $G_{ma}$, $K_{ma}$ (reference value) | |
| | $G_{ma}$ | Initial shear stiffness (at $\sigma_m' = \sigma_{ma}'$) | In-situ PS logging |
| | $K_{ma}$ | Bulk modulus (at $\sigma_m' = \sigma_{ma}'$) | |
| | $m_G$ | Dependency of confining effective stress for $G_0$ | Usually assume as 0.5 |
| | $m_K$ | Dependency of confining effective stress for $K_0$ | |
| | $\phi_f'$ | Friction angle | Laboratory test of in-situ sample |
| | C | Cohesion | |
| | $h_{max}$ | Maximum value of hysteresis damping ratio | |

$$G_0 = G_{ma}(\sigma_m' / \sigma_{ma}')^{mG} \qquad K_0 = K_{ma}(\sigma_m' / \sigma_{ma}')^{mK}$$

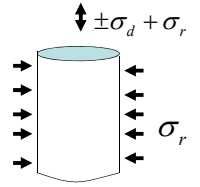


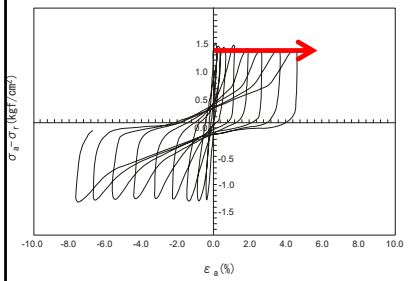
How we determined the parameters.
Example : dilatancy parameters in FLIP
(Old-type constitutive model)

| Type | Parameters | |
|---|---|---|
| Property for liquefaction (dilatancy) | $\phi_p$' | Phase transformation angle |
| | $w_1$ | Parameter for dilatancy in general |
| | $p_1$ | Parameter for dilatancy in the first half |
| | $p_2$ | Parameter for dilatancy in the second half |
| | $c_1$ | Parameter for the threshold stress level for liquefaction |
| | $S_1$ | Parameter for the limit status in liquefaction |
| | Sus | Parameter for steady states: after ver.7.1.3 |

From simulations (parametric study)
of laboratory test results
using in-situ samples
(element test simulation)

Of course, it is from
liquefaction test:
i.e. tri-axial cyclic shear test



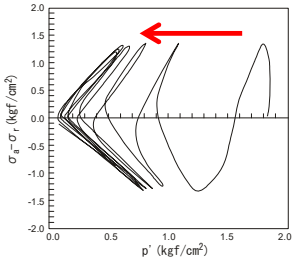
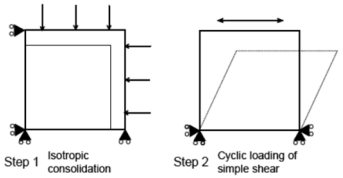
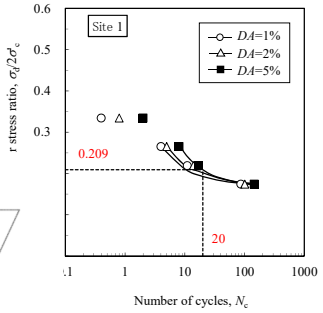
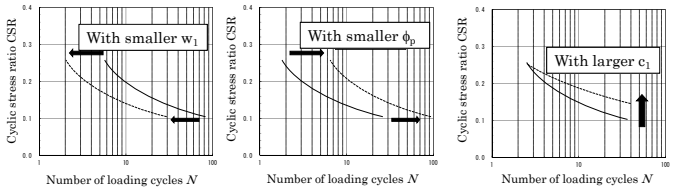




Image of the parameter
calibration (fitting) process

It's a trial and error process, repeating to succeed in simulation of element tests.



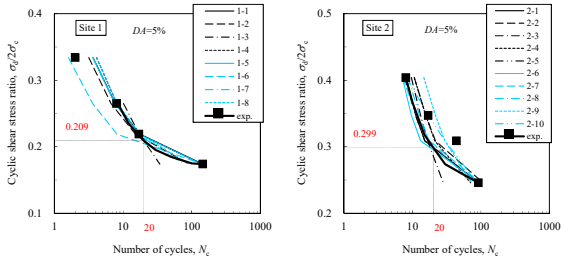




Then,
what should be the target?

Which level of strain?

1) Liquefaction resistance?
2) Strain accumulation rate? Which level of CRR?
3) How about K_alpha effect?

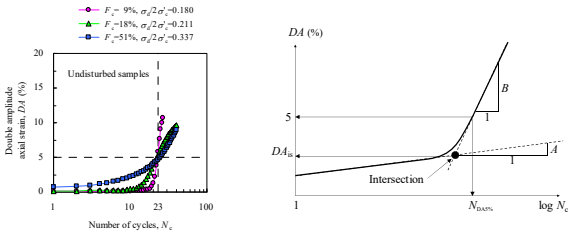
How much of agreement?



Then,
what should be the target?

1) Liquefaction resistance?
2) Strain accumulation rate?
3) How about K_alpha effect?

The difference
should be considered.
But in model
or parameters?

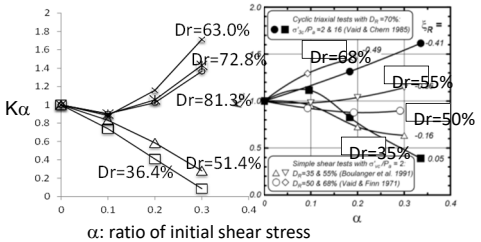



Strain accumuration model by Mikami

Then,
what should be the target?

1) Liquefaction resistance?
2) Strain accumulation rate?
3) How about K_alpha effect?

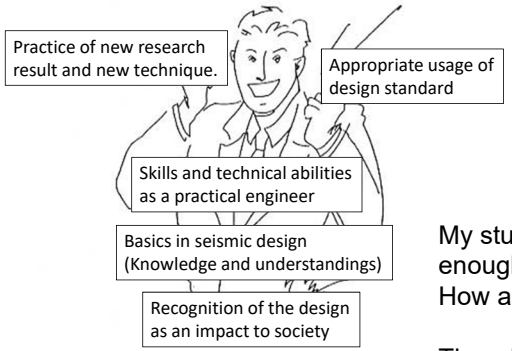
The real soil behavior
is under initial
static shear




α: ratio of initial shear stress

K_alpha effect (Bouranger) and parameter fitting example

Also, we need to think that
the engineers are not always perfect

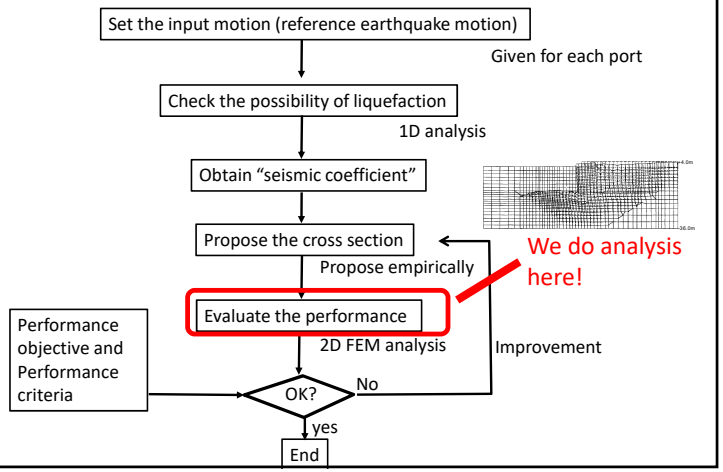



The image of
ideal earthquake engineer.
(Tanaka and Saeki, 2004).

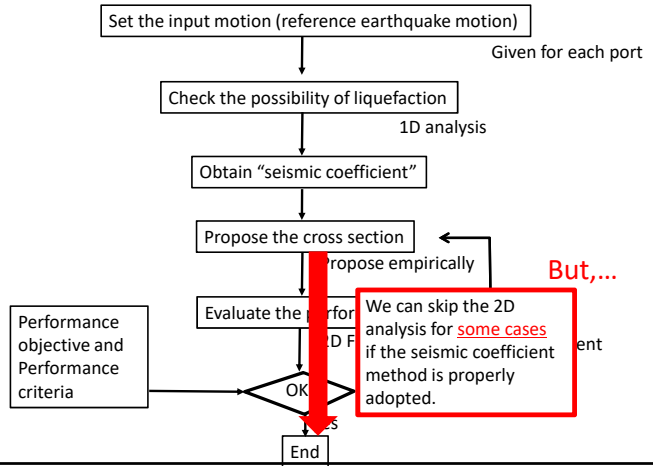
My student works good
enough?
How about me…??

Thus, PBD have
difficulties in practice.

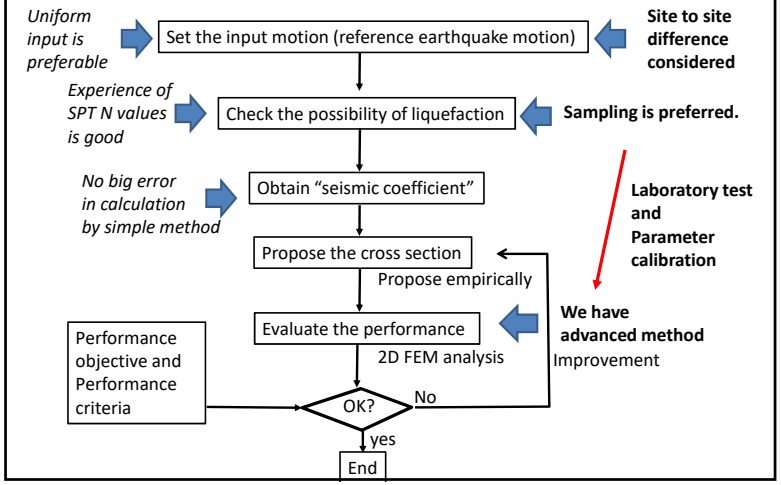
For example, the Process of Seismic Design:
in detail, for quay wall, in Japan



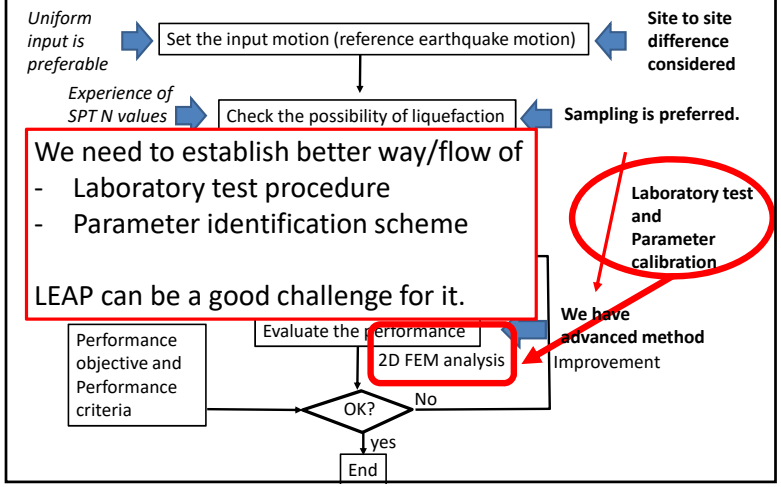
## For example, the Process of Seismic Design: in detail, for quay wall, in Japan




## *Conservative people* VS New generation




## *Thus, my conclusion today is …*




## Summary of my talk

1) We still have many issues to be considered in PBD in practice.

LEAP is a good occasion for the Validation & Verification.
But the validation depends on parameters.

2) We have already use FEM analysis as PBD tool in practice.

But to use FEM more, we need to establish better way/flow of
- Laboratory test procedure
- Parameter identification scheme

3) The detail of a possible update of the laboratory test scheme will be proposed later, from JSCE committee members.