Sociedad Mexicana de Ingeniería Geotécnica

INTERNACIONAL SYMPOSIUM ON DEEP FOUNDATIONS

3rd-4th November, 2011

Civil Engineers School of Mexico

The use of polymer support fluids in the construction of drilled shafts

presented by

Joshua R. Omer B.Sc. (Hons), M.Sc., Ph.D, R.Eng, MICE

Kingston University, London, United Kingdom.

The information is entirely based on a paper published by the Institution of Civil Engineers (Lam et al. 2010)

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Why synthetic polymer support fluids can replace bentonite slurry in bored pile and diaphragm wall construction

(a) Can be recycled many times without loss of quality thus reduces disposal costs

(b) Can be mixed much more rapidly, hence requires less area for storage and mixing

(c) Bio-degradable and hence environmentally friendly

(d) Has a low sand content when mixed and thus does not affect concrete strength

(e) Performs well both in salty and fresh water

(f) Precipitates the cuttings to the bottom of the bore thus allowing easy removal using buckets

Is the use of polymer support fluids something new?

Naturally derived polymers (e.g. xanthan gum) have been used for a long time but synthetic polymers were first used in the 1990s in the USA.

Then what are the latest findings regarding the use of sythetic polymer support fluids?

Their properties, being very different compared to bentonite, bring uncertainty about the performance of drilled shafts installed using such fluids.

Here are some of the concerns engineers commonly have:

1. *How synthetic polymers affect pile load-settlement characteristics compared to bentonites*

2. *Whether a polymer-supported bore can be exposed for a long time (> 12 hrs) without compromising the performance of the completed pile*

3. The effect of polymer fluid on the quality of the hardened pile concrete

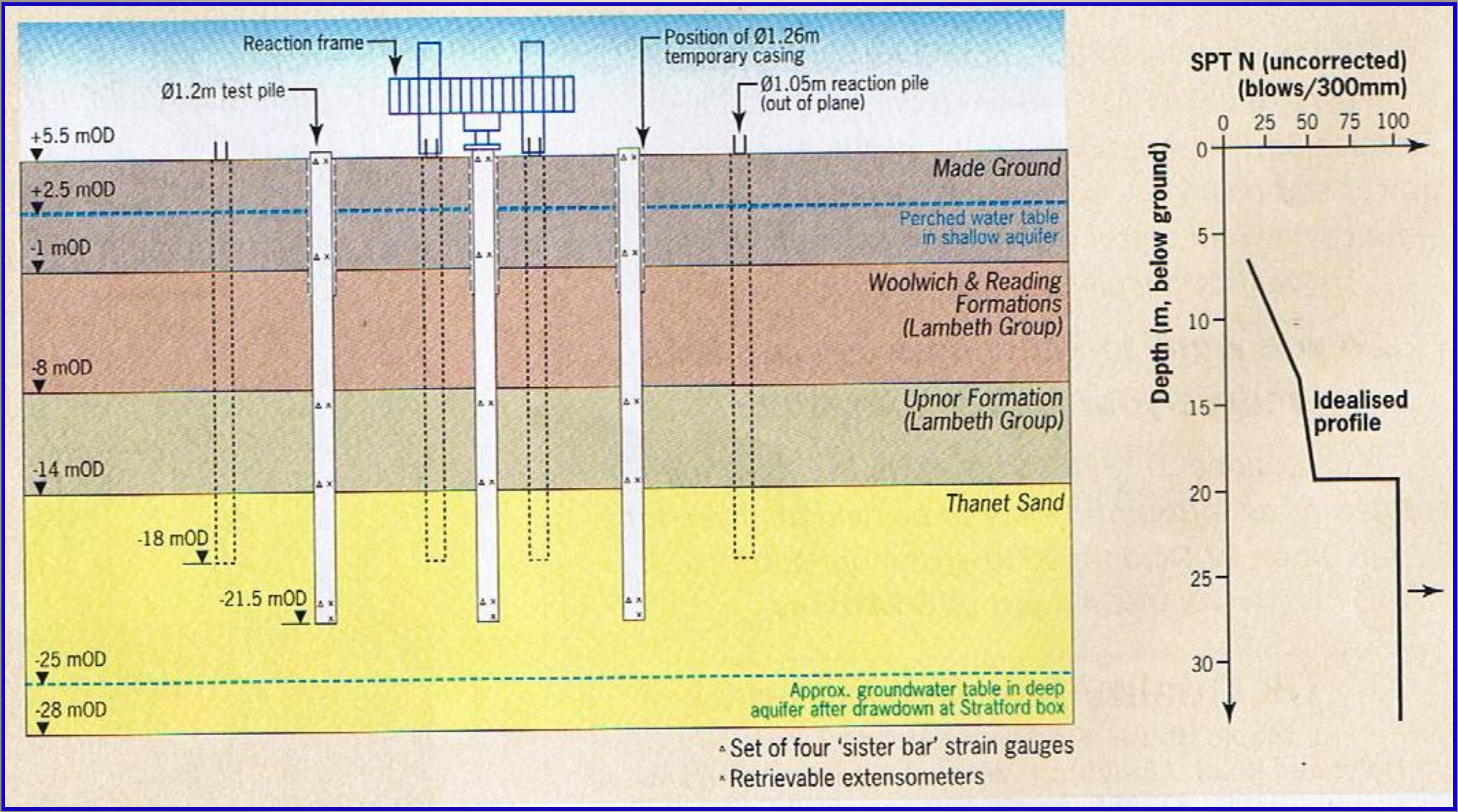
4. The amount of sediment collecting at the base of the pile.

5. If and how the re-bar bond strength is affected by the support fluid

6. What monitoring and control measures are necessary for specific polymers

In order to answer the above questions research findings published by ICE (Lam et at. 2010) is presented here. This involved load-testing by Balfour Beatty and Oxford University at a location in London, UK.

Ground conditions & pile test arrangement (Lam et al.2010)



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Strata details and ground water conditions:

*From -1mOD to -8mOD : Woolwich & Reading formations (SPT "N" = 15 to 44):
…this is sandy CLAY with shell fragments and is part of the Lambeth group*

*From -8mOD to -14mOD : Upnor formations (SPT "N" = 44-52):
…this is slightly gravelly sandy CLAY and also forms part of the Lambeth group*

From -14mOD to bottom of SI borehole: Thanet Sand (SPT "N" > 100):

Permanent ground water level = -25mOD : (due to ground water control measures undertaken for the Stratford box)

Pile installation programme (**Lam et al.2010)

***Three** bored piles with nominal dia. = 1.2m ; length = 27 m at spacings of 6m centres.*

The pile bases were at -21.5mOD which is within the Thanet Sand.

Pile B1	**Formed with bentonite**	**(Used as a benchmark)**	**Age at test = 25 days**
Pile P1	**Formed with synthetic polymer fluid**	**Fluid exposed for 7.5hrs**	**Age at test = 25 days**
Pile P2	**-Do-**	**Fluid exposed for 26hrs**	**Age at test = 25 days**

Properties of synthetic polymer support fluids used in the 3 piles (Lam et al.2010)

Fluid details and exposure time					Fluid test results[a]			
Pile number	Name and supplier	Dosage	Total fluid-soil exposure time (h)	Hours in hole at time of fluid tests (h)	Marsh funnel viscosity (s)	Density (g/cm^3)	Sand content (%)	pH (-)
B1	Berkbent 163 (Steetley Bentonite)	$40kg/m^3$	7.5	3	34/40/41	1.02/ 1.10/ 1.15	0/6.8/10	10.5/ 10.3/ 10.3
P1	SlurryPro CDP (KB Intl)	$1.0kg/m^3$ for CDP $0.08kg/m^3$ for LA-1 and 10L of 1% MPA solution	7.5	5	70/56/56	1.00/ 1.02/ 1.03	0/0.2/0.2 (1.3)[b]	11.2/ 11.2/ 11.2
P2			26	23	69/50/50	1.00/ 1.02/ 1.02	0/0.1/0.1 (1.4)[b]	11.0/ 11.0/ 11.0

Key: 34=fresh fluid from middle of tank, 40=used fluid from middle of bore; 41=used fluid from bottom of bore

Note: Values in parentheses are sand contents at bottom of pile bores before addition of additive MPA

Important points to note from the fluid properties (previous Table):

(1) The Marsh funnel viscosity, density, pH and sand content of the polymer fluid was very diffrent to those of bentonite

(2) The sand content of the initial bentonite exceeded the limit of 4% (FPS, 2006) and so it was exchanged for a fresh bentonite prior to concreting – to prevent accumulation of sediments at the bottom of the bore.

Procedure for excavation and pile base cleaning (Lam et al.2010):

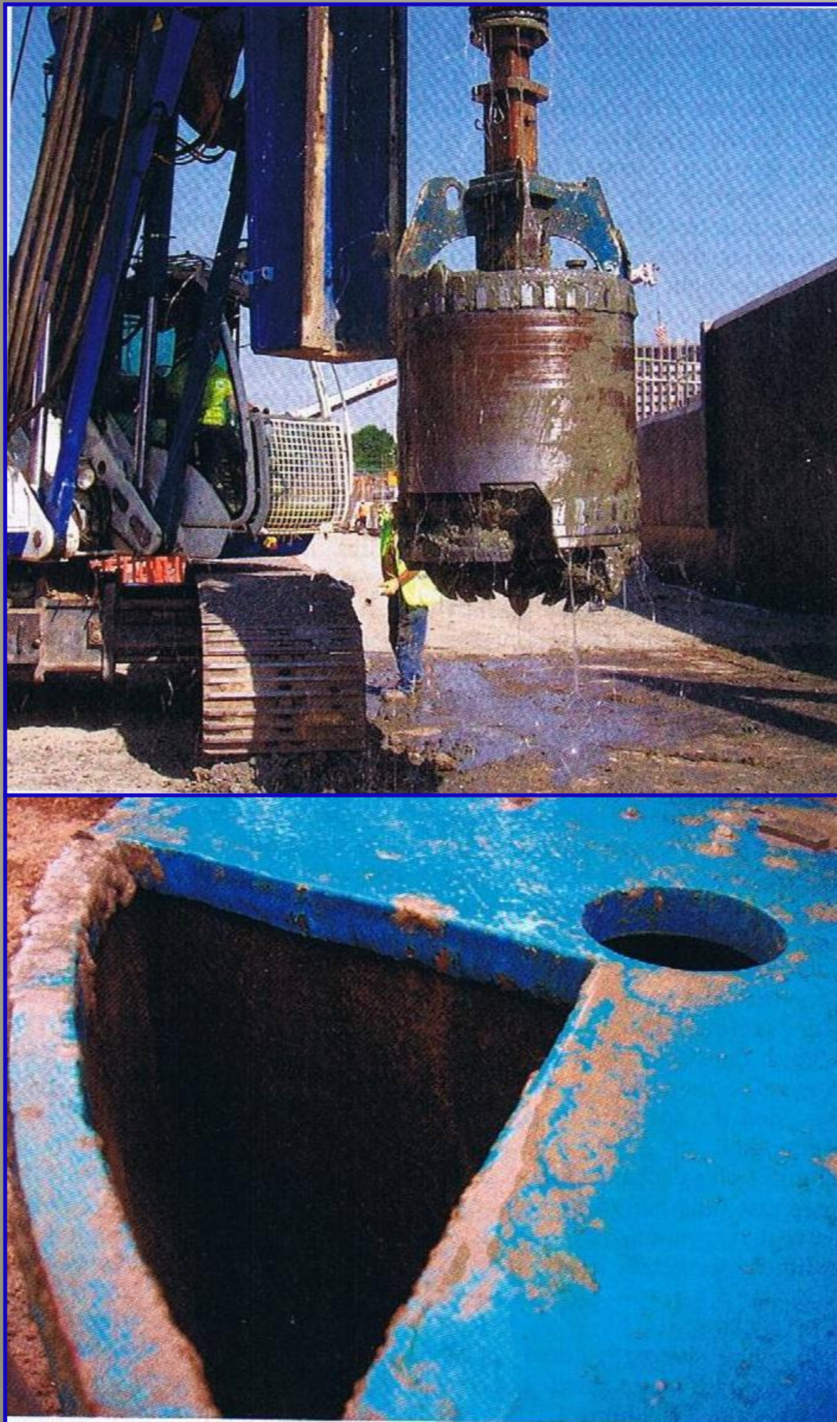
Step 1: Insert steel casing through the made ground down to the top of the Woolwich & Reading layer

Step 2: Excavate in the dry down to near the base of the Lambeth Group

Step 3: Flood the pile bore with the support fluid (actual depth at which fluid was introduced was about -11.5mOD, depending on the stability of the bore)

Step 4: Excavate under support fluid using a twin-auger or vented digging bucket (both tools allow drainage of fluid back to the hole during tool extraction …. Thus preventing development of suction in the fluid column)

Twin-flight auger immediately after extraction from a polymer supported bore
(Lam et al.2010)



Vented digging bucket immediately after extraction from a polymer supported pile bore

(Lam et al.2010)

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3rd-4th November, 2011

Sociedad Mexicana de Ingeniería Geotécnica

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***Step 5**: Check the cleanliness of the base by lowering a metal plate to the bottom*

***Step 6**: On hitting the bottom the plate impact is graded 1 – 5 (Berry, 2009).*

…All three test piles recorded grade 3, implying a distinct base with only a small amount of loose soil.

Procedure for pile testing and concrete sampling (Lam et al.2010)

Pile test method: *Maintained load test (ICE 2007 - Specification for Piling and Retaining Walls: Institution of Civil Engineers)*

For piles B1 and P2 concrete cubes for comp. strength and elastic modulus tests were sampled from:

(a) chutes of the delivery trucks, and
(b) pile tops i.e. interface between freshly placed concrete and the support fluid

This was to investigate how different support fluids affect concrete quality.

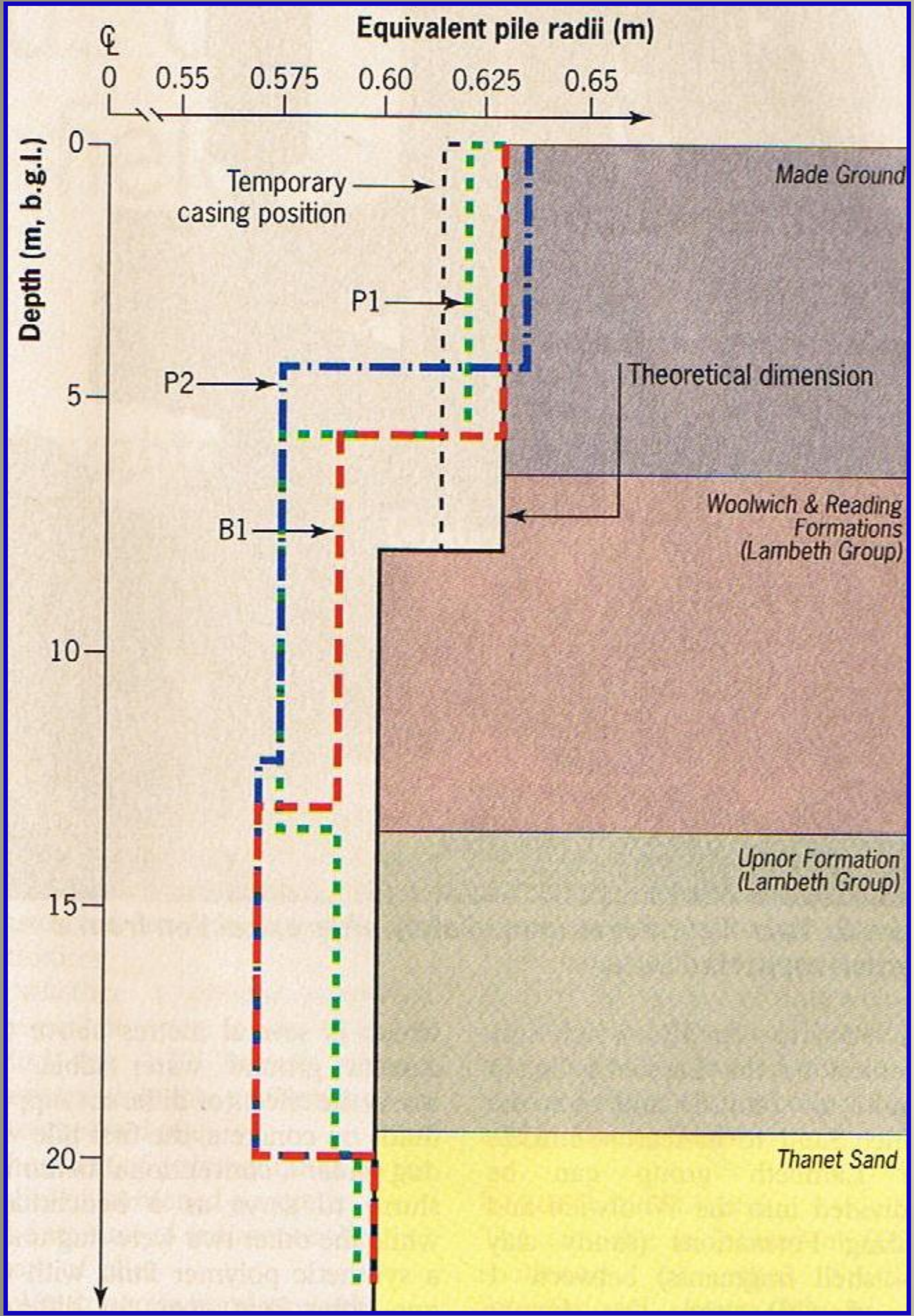
Procedure for concreting:

- ***Concrete type**: self compacting : class C28/35 CIIB-V S4 DC-3*

- ***Method of placement**: Discharged into pile hole using a tremie pipe (its tip kept below rising concrete level at all times)*

- ***Initially tremie pipe rested at base** while filled with concrete then slightly lifted to provide a surge effect to allow an initially high discharge rate (1.2 m^3/min) to flush sediments aside (thereafter discharge rate = 0.5 m^3/min) .*

- ***Actual pile radius as cast**: This was determined by measuring succesive rises in concrete level in bore for every truck load discharged.*



Does polymer fluid and its exposure time affect the sidewall profile?

As seen, the three pile bores had similar profiles despite the 26 hr exposure time (P2) (Lam et al.2010)

(considering there are also other factors e.g. concrete volume variations, wastage etc)

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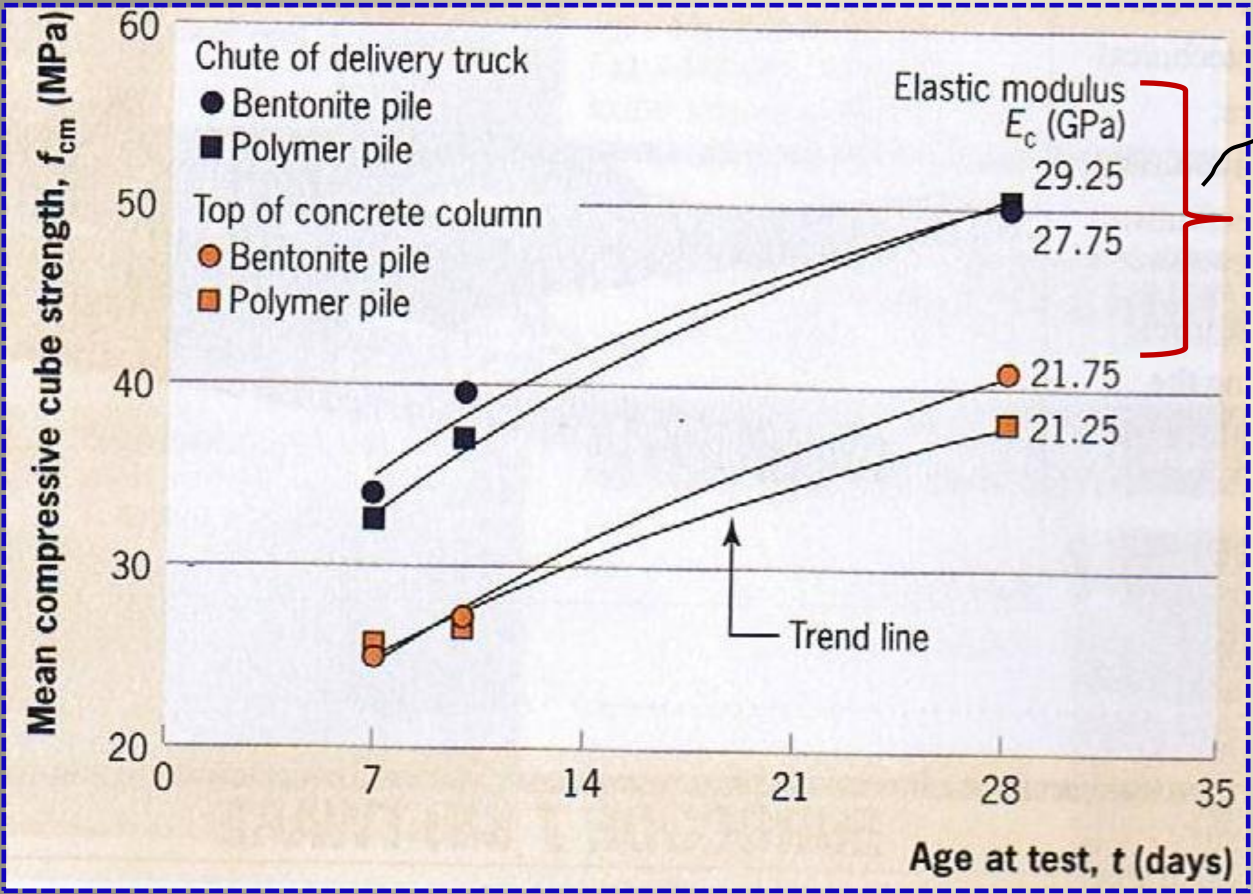
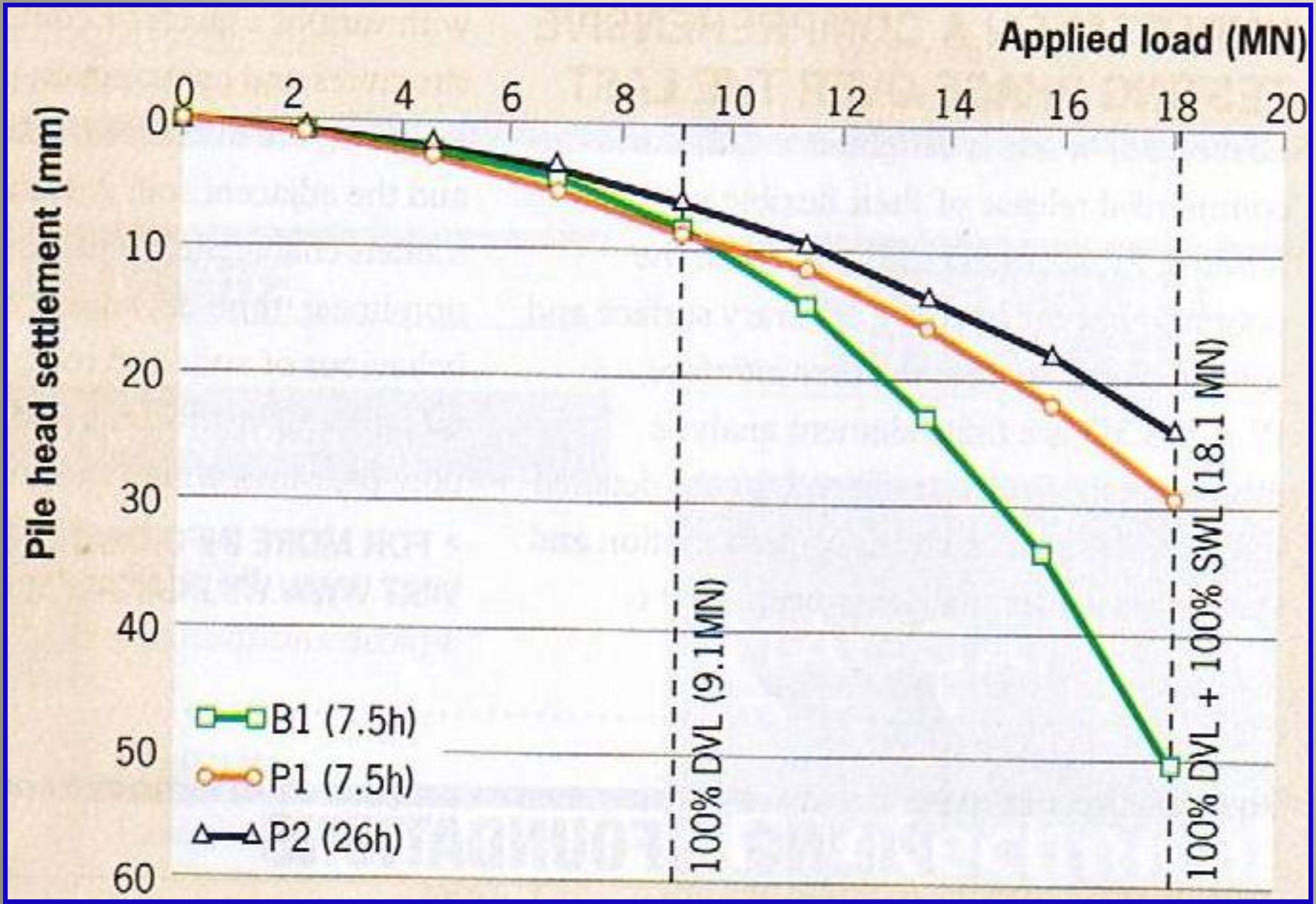
Does polymer fluid affect concrete strength any more than bentonite does?



Both comp strength and elastic modulus reduced by 26% for polymers and 29% for bentonite

Thus the intermixing of concrete with support fluid during concreting has virtually the same effect for bentonite and polymers.
[by Lam et al.(2010): from Jeffries and Mavroulidou(2003)]

Does polymer fluid affect the pile load-settlement characteristics more than bentonite does?



Comparing the 3 piles:

Settlements at each stage first projected to infinite time (hyperbolic method)

..... to remove time-dependent and consolidation effects

Chart by Lam et al.(2010)

At proof load, the polymer piles are much stiffer than the bentonite piles

At 100% design verification the three piles have similar stiffnesses

Finally, it is both surprising and reassuring to note that polymer pile P2, despite the 26 hrs fluid exposure, has even a better response than P1

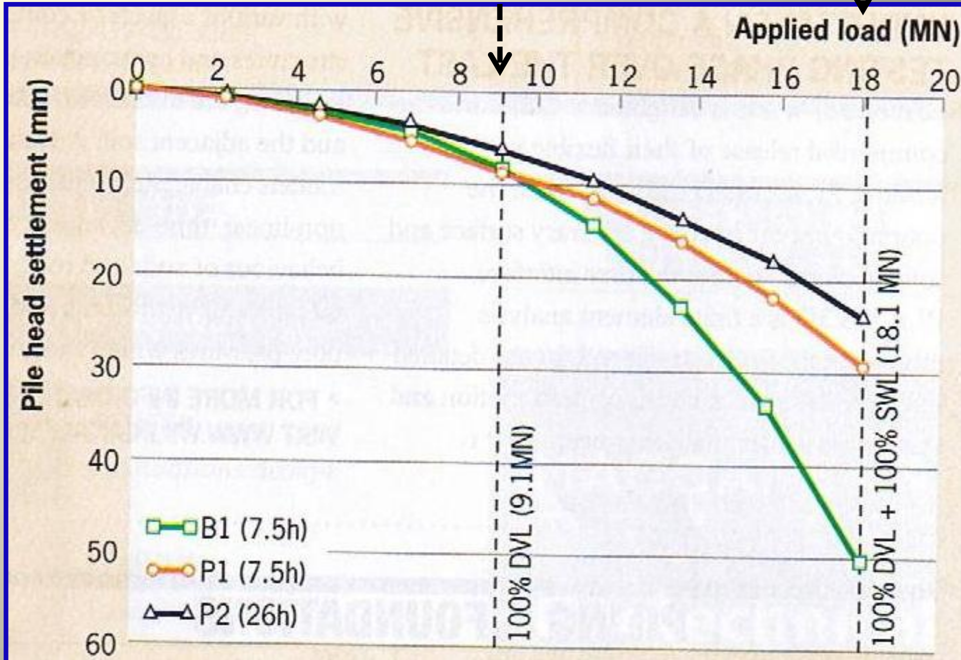


Chart by Lam et al.(2010)

CONCLUSIONS FROM THIS RESEARCH

In addition to the advantages described in slide No. 1, the pile tests demonstrated the following extra benefits of polymer support fluids:

1. **Synthetic polymer support fluids do NOT affect the strength of concrete any more than bentonite slurry does.**
2. **The condition of a pile bore does NOT worsen with extended exposure time of synthetic polymer support fluid.**
3. **The condition of a pile bore does NOT worsen with extended exposure time of synthetic polymer support fluid.**
4. **A polymer pile even has a greater load-settlement stiffness at loads above the DVL as compared to a bentonite pile.**

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THANK YOU !

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