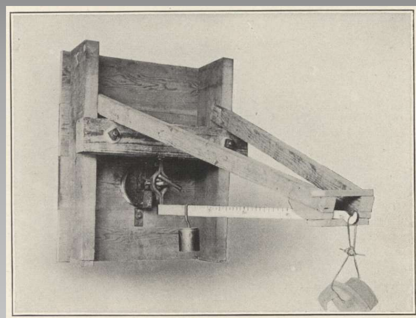
CHARACTERIZATION OF CONCRETE FOR THE PREDICTION OF FORMWORK PRESSURE

iowa better concrete conference

NOVEMBER 10, 2021



Pressure of Concrete on Forms, Maj. Francis R. Shunk, U.S. Army Corps of Engineers, July-Sept. 1909
Professional Memoirs, Corps of Engineers, Vol. 1, No. 3, pp. 247-260 – by permission of the Society of American Military Engineers.

ERIC PETERSON
ericp@webcor.com
WEBCOR CONCRETE

IN THE LATE SUMMER AND FALL OF 1908, U.S. ARMY CORPS OF ENGINEERS, ST. PAUL DISTRICT COMMANDER, MAJ. FRANCIS SHUNK WORKED ON THE CASTING OF THE LOCK 1 WALLS ON THE MISSISSIPI RIVER BETWEEN ST. PAUL AND MINNEAPOLIS. IT CONSISTED OF A SERIES OF MONOLITHIC BLOCK CASTINGS 25.75' TALL. THE CONCRETE UNIT WEIGHT WAS 152 LB/CF.

Photo Source: Library of Congress

EARLY IN THE PROCESS THEY MADE THE FOLLOWING FUNDEMENTAL OBSERVATIONS:

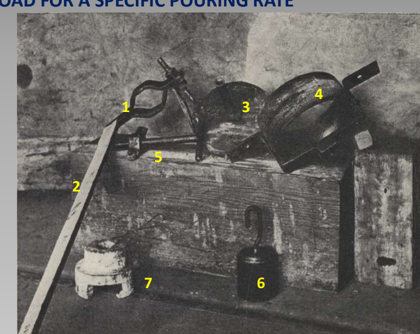
- FORMWORK WHICH WAS ADEQUATE DURING THE SUMMER WAS NO LONGER ADEQUATE IN THE COLDER WEATHER OF THE FALL CONCLUDING THAT, SETTING RATE AND FORMWORK PRESSURE WAS A FUNCTION OF CONCRETE TEMPERATURE
- THEY ALSO UNDERSTOOD THAT FORMWORK PRESSURE WAS A FUNCTION OF THE RATE OF PLACEMENT.

MAJOR SHUNK STARTED A PROGRAM OF MEASURING FORMWORK PRESSURE AND GRAPHICALLY RECORDED THIS INFORMATION AS A FUNCTION OF THE RATE OF POUR (VERTICAL FEET /HR) AND CONCRETE TEMPERATURE

MAJ. SHUNK'S GOALS:

- A SAFE POURING RATE AT A GIVEN CONCRETE TEMPERATURE FOR A GIVEN FORM STRUCTURE
- CONSERVATIVE FORMWORK DESIGN LOAD FOR A SPECIFIC POURING RATE AND CONCRETE TEMPERATURE

1. DUAL PIVOT WEIGHT ARM ACTUATOR
2. GRADUATED, 5'-0" LONG WEIGHT ARM
3. 9.23" ϕ PISTON
4. PISTON CYLINDER
5. ADJUSTABLE PISTON ROD
6. WEIGHT
7. WEIGHT



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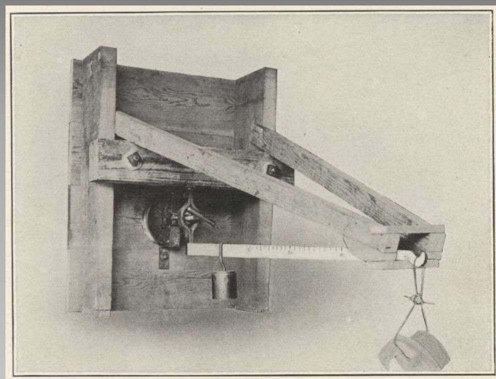
MAJ. SHUNK'S FORMWORK PRESSURE SENSOR



THIS SENSOR WAS INSTALLED 18 INCHES FROM THE BOTTOM OF THE PLACEMENT

Source: Pressure of Concrete on Forms, Maj. Francis R. Shunk, U.S. Army Corps of Engineers, July-Sept. 1909 Professional Memoirs, Corps of Engineers, Vol. 1, No. 3, pp. 247-260 – by permission of the Society of American Military Engineers.

TIME REQUIRED FOR THE BEGINNING OF STRUCTURE DEVELOPMENT

The method of deducing the final curves was as follows: The pressure on the piston at first is that due to pressure of a liquid weighing 152 pounds per cubic foot. After a time, the pressure on the piston becomes less than the liquid pressure, because the concrete begins to act as a solid, and is then equal to the liquid pressure minus a certain resistance due to setting and arch action, which (for lack of a better name) has been called strength. The time at which this strength begins to show varies with temperature, pressure, condition of rest or agitation, and, perhaps, other things. From the data available a formula for time of initial strength has been deduced, which is $T = C + 150/R$, in which T is time in minutes after filling has begun, when concrete begins to show strength, R is rate of filling in vertical feet per hour, and C is a constant depending on temperature of concrete. Values of C for the usual temperatures are as follows:

Temperature.	*C.*
80	20
70	25
60	35
55	42
50	50
40	70

The temperature considered here, as elsewhere in this discussion, is the temperature of the mixture in the form.

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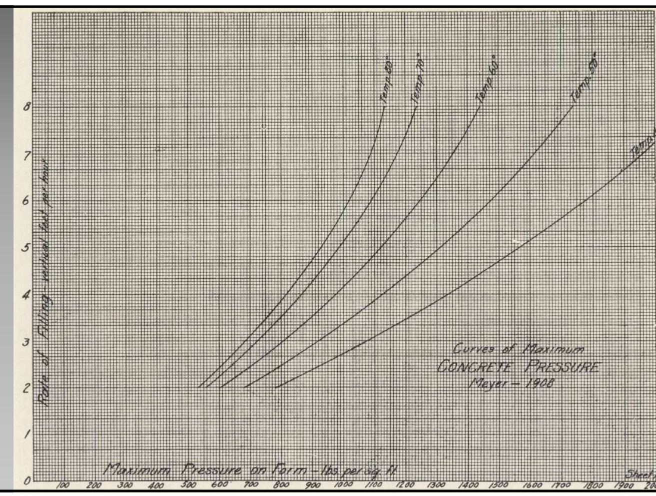
VALUES FOR R = 3, 4 & 5 FT/HR FOR BEGINNING OF STRUCTURE DEVELOPMENT BASED UPON THE EXPRESSION DERIVED BY SHUNK

Concrete Temperature (°F)	C	R (ft/hr)	$T = C + \frac{150}{R}$, (min.)
80	20	3	70
70	25	3	75
60	35	3	85
55	42	3	92
50	50	3	100
40	70	3	120
80	20	4	57.5
70	25	4	62.5
60	35	4	72.5
55	42	4	79.5
50	50	4	87.5
40	70	4	107.5
80	20	5	50
70	25	5	55
60	35	5	65
55	42	5	72
50	50	5	80
40	70	5	100

WHY DOES THE TIME FOR INITIAL STRENGTH DECREASE WITH INCREASING PLACEMENT RATES?
– ARCHING?

MAJOR SHUNKS TEAM DEVELOPED PRESSURE CURVES BASED UPON PLACEMENT RATE AND CONCRETE TEMPERATURE

(NONVIBRATED CONCRETE)



I am far from claiming absolute accuracy for the results obtained, but I think they are sufficiently exact for the purpose, which is not to establish a theory of molecular physics, but only to find a practical rule for determining strength of forms or rate of filling. During the coming season I expect to use a larger piston (2 square feet in area if possible) and to make a greater number of measurements. Advice will be cheerfully received.

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ACI COMMITTEE 622

- IN 1955 ACI COMMITTEE 622 WAS FORMED FOR THE PURPOSE OF MAKING RECOMMENDED DESIGN ASSUMPTIONS FOR THE LATERAL PRESSURE OF CONCRETE ON VERTICAL FORMWORK.
- THEIR SECOND REPORT WAS PUBLISED IN THE JOURNAL OF THE AMERICAN CONCRETE INSTITUTE - V. 30, NO. 2, AUG 1958, PROCEEDINGS V. 55
- ACI COMMITTEE 622 BECAME ACI COMMITTEE 347.

COMMITTEE 622 CONSISTED OF FORMWORK MANUFACTURERS , CONTRACTORS AND FORMWORK ENGINEERS

Title No. 55-10

Pressures on Formwork*

Reported by ACI Committee 622

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Chairman

JOHN BANKER
FRANK H. BEINHAUER
H. P. CERUTTI
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N. L. DOE
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O. G. SHARRAR
M. L. STEPHENS
P. R. STRATTON
WILLIAM R. WAUGH
WILLIAM H. WOLF

FACTORS AFFECTING FORMWORK PRESSURE CONSIDERED BY COMMITTEE 622

- RATE OF PLACEMENT
- CONSISTENCY OF CONCRETE
- WEIGHT OF CONCRETE
- MAXIMUM AGGREGATE SIZE
- TEMPERATURE OF CONCRETE MIX
- AMBIENT TEMPERATURE
- SMOOTHNESS AND PERMEABILITY OF FORMS
- CROSS SECTION OF FORMS
- EFFECTOF CONSOLIDATION BY VIBRATION
- PLACING PROCEDURES
- PORE WATER PRESSURE
- TYPE OF CEMENT
- DEPTH OF PLACEMENT

COMMITTEE 622 HAD THE GOAL OF PROVIDING USERS AN EXPRESSION WHICH WAS BOTH EASY TO APPLY AND REMEMBER

$$p = 150 + \frac{9000R}{T}$$ (maximum values: 3,000 psf for columns and 2000 psf for walls)

Where:
p **= the maximum lateral pressure (psf)**
R **= the vertical rate of placement (ft/hr)**
T **= the temperature of the concrete in the formwork (°F)**
The effect of vibration is included in the coefficient (9000) of *R*

LINEAR FOR A GIVEN TEMPERATURE WHERE THE SLOPE IS = 9000/T

QUALIFIERS:
- Revibration is allowed only while concrete is still plastic and is minimized
- External vibration is prohibited
- Concrete unit weight is assumed to be 150 pcf
- Concrete slump is ≤ 4 in.

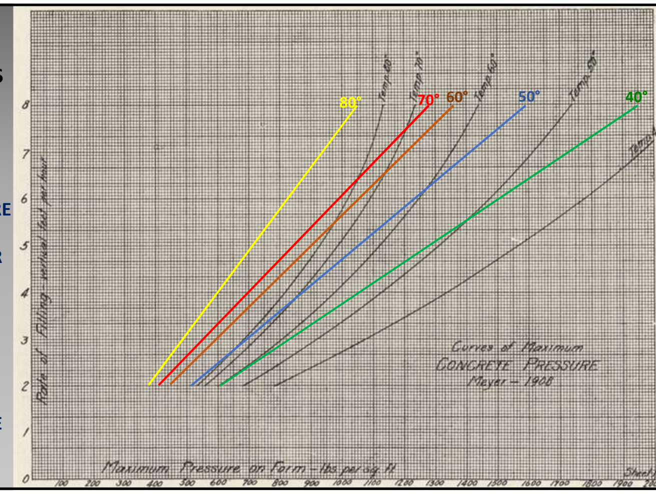
THE CONCLUSIONS OF THE REPORT BY COMMITTEE 622 PROVIDE A DESIGN EXPRESSION FOR WALLS WHERE IF, R > 7FT/HR:

$$p = 750 + \frac{2{,}800R}{T}\ (maximum\ of\ 2{,}000\ psf)$$

This was later modified to:

$$p = 150 + \frac{43{,}400}{T} + \frac{2{,}800R}{T}$$
$$(maximum\ of\ 2000\ psf\ or\ 150\ h, whichever\ is\ least)$$

OVERLAY OF ACI COMMITTEE 622 EQUATION RESULTS ONTO THE GRAPHS OF MAJ. SHUNK



OBSERVATIONS:
1. SHUNKS VALUES ARE GENERALLY MORE CONSERVATIVE, FOR R ≤ 8 FT/HR

2. COMMITTEE 622 GRAPHED LINES HAVE THE CHARACTERISTIC OF A DISPLACED TANGENT LINE TO THE SHUNK CURVES

ACI 347-01
THE INCORPORATION OF UNIT WEIGHT AND CHEMISTRY COEFFICIENTS C_w and C_c

UNIT WEIGHT COEFFICIENT, C_w (INCH-POUND)

1. $W_c < 140pcf;\ C_w = 0.5\left[1 + \left(\frac{W_c}{145pcf}\right)\right]$

LWC example: $0.5\left[1 + \left(\frac{120}{145pcf}\right)\right] = 0.91$

2. $140pcf \le W_c \le 150pcf;\ C_w = 1.0$

3. $150pcf < W_c;\ C_w = \frac{W_c}{145pcf}$

Where W_c is the actual weight of the concrete and *pcf* = pounds per cubic foot

ACI 347-01
THE INCORPORATION OF UNIT WEIGHT AND CHEMISTRY COEFFICIENTS C_w and C_c

CHEMISTRY COEFFICIENTS C_c

CEMENT TYPE OR BLEND	C_c
Types I & III w/o Retarders*	1.0
Types I & III with Retarders*	1.2
Other Types or Blends Containing < 70% Slag or < 40% fly ash w/o Retarders*	1.2
Other Types of Blends Containing < 70% Slag or < 40% fly ash with Retarders*	1.4
Blends with > 70% slag or > 40% fly ash	1.4

*Retarders include any admixture, such as a retarder, retarding water reducer or retarding high-range water-reducing admixture, that delays setting of concrete

ACI 347-01
THE INCORPORATION OF UNIT WEIGHT AND CHEMISTRY COEFFICIENTS C_w and C_c

LATERAL PRESSURE EQUATIONS

For Columns:

$$p = C_w C_c \left[150 + \frac{9000R}{T}\right]$$

For Walls:

$$p = C_w C_c \left[150 + \frac{43,400}{T} + \frac{2800R}{T}\right]$$

For All Other Cases:

$$p = W_c h$$

ACI 347-14 – PROVIDES FURTHER QUAIFICATIONS REGARDING WHICH OF THE THREE EQUATIONS ARE TO BE USED

LATERAL PRESSURE EQUATIONS	APPLICATION
For Columns: $p = C_w C_c \left[150 + \frac{9000R}{T}\right]$	Slump ≤ 7", Vibration depth is < 4ft for: ▪ Any column ▪ Walls where h is ≤ 14 ft and R < 7 ft/hr
For Walls: $p = C_w C_c \left[150 + \frac{43,400}{T} + \frac{2800R}{T}\right]$	Slump ≤ 7", Vibration depth is < 4ft for: ▪ Walls where h > 14 ft and R < 7ft/hr ▪ Walls where 7 ft/hr ≤ R ≤ 15 ft/hr
For All Other Cases: $p = W_c h$	▪ Any element where slump > 7" ▪ Any element where vibration depth > 4 ft and slump is ≤ 7" ▪ Walls where R > 15 ft/hr

INPUT CHARACTERISTICS:
- RATE OF HYDRATION (Indirectly - T, C_c)
- CONCRETE UNIT WEIGHT (C_w)
- ELEMENT TYPE (Walls or Columns)
- SLUMP
- CONCRETE UNIT WEIGHT (C_w)
- CASTING RATE (R)
- HEIGHT OF PLACEMENT (h)

ACI PRC 237.2-21 – FORM PRESSURE EXERTED BY SELF-CONSOLIDATING CONCRETE: PRIMARY FACTORS AND PREDICTION MODELS

THE PRIMARY DIFFERENCE BETWEEN FORMWORK PRESSURE PREDICTION MODELS USED FOR SELF CONSOLIDATING CONCRETE (SCC) AND THOSE USED FOR CONVENTIONALLY VIBRATED CONCRETE (CVC) IS THAT THE SCC MODELS TAKE INTO CONSIDERATION THE RHEOLOGICAL PROPERTIES OF YIELD STRESS, VISCOSITY AND THIXOTROPY, WHEREAS THE CVC MODELS ARE BASED UPON INITIAL SLUMP, VIBRATION DEPTH AND THE RATE OF STRUCTURE BUILDING THROUGH HYDRATION AS A FUNCTION OF TEMPERATURE AND BINDER CHEMISTRY

THE SECOND PRINICPLE DIFFERENCE BETWEEN SCC MODELING OF FORMWORK PRESSURE AND THAT CURRENTLY USED FOR CVC IS THAT EACH SCC MIXTURE IS PHYSICALLY CHARACTERIZED. THESE CHARACTERIZATIONS ARE USED IN THE FORMWORK PRESSURE PREDICTION MODELS.

ACI PRC 237.2-21 – FORM PRESSURE EXERTED BY SELF-CONSOLIDATING CONCRETE: PRIMARY FACTORS AND PREDICTION MODELS

THIXOTROPY IS A REVERSIBLE, ISOTHERMAL, TIME-DEPENDENT DECREASE IN VISCOSITY WHEN A FLUID IS SUBJECTED TO AN INCREASED SHEAR STRESS OR SHEAR RATE (MEWIS 1979). IT IS THE REVERSABILITY OF THIS PROCESS WHICH ACCOUNTS FOR STRUCTURE BUILDING PRIOR TO WHEN HYDRATION BECOMES THE DOMINANT PROCESS OF SOLIDIFICATION. THIXOTROPY IS RESULT OF THE FLOCCULATION OF THE CEMENTITIOUS MATERIALS WHICH CAN BE INFLUENCED BY OTHER MIXTURE CONSTITUENTS OR PROPORTIONS.

FLOCCULATION, RELATIVE TO SCC, IS THE CLUSTERING OF BINDER PARTICLES IN CEMENT PASTE AT REST CAUSED BY INTERPARTICLE FORCES, WHICH RESULTS IN AN INCREASE IN STATIC YIELD STRESS.

ACI PRC 237.2-21 – FORM PRESSURE EXERTED BY SELF-CONSOLIDATING CONCRETE: PRIMARY FACTORS AND PREDICTION MODELS

PRC 237.2-21, CHAPTER 6 DESCRIBES FOUR MODELS FOR PREDICTING FORMWORK PRESSURE FOR PLACEMENTS MADE USING SELF-CONSOLIDATING CONCRETE (SCC):

Gardner et al. (2012) $P_{max} = w_c R\left[t_H - \frac{{t_H}^2}{2t_o}\right]$, for $t_H < t_o$ and,

$$P_{max} = \frac{w_c R t_o}{2}, \text{ for } t_H \geq t_o$$

The Gardner et al. model extrapolates the time for the slump flow to equal zero.

INPUT PARAMETERS:

- Concrete unit weight (w_c)
- Casting rate (R)
- Linear extrapolation of the time for the slump flow to = 0 (t_o)
  - $t_o = t_{15.75}\left[\frac{initial\ slumpflow}{initial\ slump\ flow - 15.75}\right]$
- Time to fill the formwork to height (t_H)

ACI PRC 237.2-21 – FORM PRESSURE EXERTED BY SELF-CONSOLIDATING CONCRETE: PRIMARY FACTORS AND PREDICTION MODELS

Khayat and Omran (2010b)

$$P_{max}(Pa) = \frac{w_c g H}{100}\left[95.9 - 3.84H + 0.71R + 4.1D_{min} - 0.29PV\tau_{0rest}(t)\right] \times f_{MSA} \times f_{WP} \text{ (SI)}$$

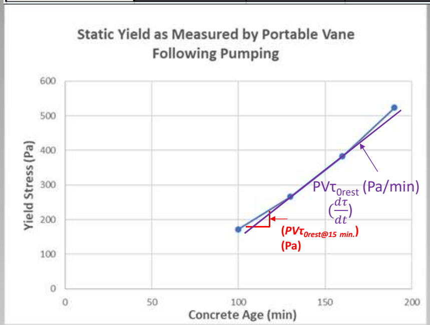
The Khayat and Omran model used linear regression analysis to fit 780 data points in a series of measurements utilizing a pressure column. Khayat and Omran also have published models which take into consideration concrete temperature and reinforcing density

INPUT PARAMETERS:

- Concrete unit weight (w_c)
- Element height (H)
- Casting rate (R)
- Minimum lateral dimension of the formwork (D_{min})
- Rate of change in yield stress with rest time ($PV\tau_{0rest}(t)$)
- Correction factor for the maximum size aggregate (f_{MSA})
- Correction factor for the waiting periods between successive lifts (f_{WP})

PORTABLE VANE TEST FOR DETERMINING YIELD STRESS

Portable Vane	Mix P10PB2CS Batch Time: 09:58			
	At End of System			
Minutes from Batch	Filling Height, h (m)	Max Torque (Nm)	Temp (°F)	Static Yield (Pa)
100	0.250	0.40		172
130	0.200	0.50		266
160	0.150	0.55		383
190	0.100	0.52		523



ACI PRC 237.2-21 – FORM PRESSURE EXERTED BY SELF-CONSOLIDATING CONCRETE: PRIMARY FACTORS AND PREDICTION MODELS

Tejeda-Dominguez et al. (2005) $P_{max} = w_c RtC(t)$

This model is based upon the assumption that the lateral pressure is a function of the vertical pressure and the shear strength of the SCC, where,

$$C(t) = \frac{C_o}{(at^2+1)^{\alpha}}$$

INPUT PARAMETERS:

- Concrete unit weight (w_c)
- Casting rate (R)
- The input values, for $C(t)$, are obtained by multiple measurements of a small-scale column
- The variables in the characteristic, hyperbolic function, $C(t) = \frac{C_o}{(at^2+1)^{\alpha}}$, C_o, a and α are determined by best fit.
- $C(t)$ is determined by measuring the lateral pressure in the small column and normalizing this with the theoretical hydrostatic pressure, $(P_{hydrostatic})$.
- $C(t)$ is maximized when $t = \sqrt{\frac{1}{2a(\alpha-1)}}$.
- C_o determines the initial value of the function and typically ranges between 0.9 and 1.00, where a value of 1 indicates full hydrostatic pressure.

ACI PRC 237.2-21 – FORM PRESSURE EXERTED BY SELF-CONSOLIDATING CONCRETE: PRIMARY FACTORS AND PREDICTION MODELS

Ovarlez and Roussel (2007), $P_{max} = w_c H\left[1 - \frac{H\tau_{0rest}(t)}{w_c eR}\right]$

In words, $P_{max} = P_{hydrostatic}\left[1 - \frac{Placement\ height \times change\ in\ yield\ stress\ with\ rest\ time(h)}{concrete\ unit\ weight \times form\ width \times casting\ rate\ ft/hr)}\right]$

This model considers SCC as a confined elastic material where the maximum stress sustainable by an internal plane is the yield stress of the concrete. The pressure at a given depth (*H*) is equal to a hydrostatic pressure reduced by the vertical stress at the walls which is between 0 and the yield stress of the SCC at rest.

INPUT PARAMETERS:

- Concrete unit weight (w_c)
- Depth within the element (*H*)
- Casting rate (*R*)
- Width or diameter of the casting (*e*)
- Rate of change of static yield stress (*t*) ($\tau_{0rest}(t)$)

SUMMARY OF CHARACTERIZED QUANTITIES FOR BOTH CVC AND SCC

CURRENT MODELS FOR CVC USE:

- RATE OF PLACEMENT
- UNIT WEIGHT OF CONCRETE
- CONCRETE TEMPERATURE
- BINDER TYPES, POZZOLANS AND THEIR COMBINATIONS

USED AS A DISCRIMINANT:

- SLUMP
- INTERNAL VIBRATION DEPTH
- ELEMENT TYPE
- HEIGHT OF PLACEMENT

PRESENTED MODELS FOR SCC USE:

- RATE OF PLACEMENT
- UNIT WEIGHT OF CONCRETE
- CONCRETE TEMPERATURE
- DEPTH OF PLACEMENT
- TOTAL TIME OF PLACEMENT
- WAITING PERIOD BETWEEN LIFTS
- DECAY RATE OF SLUMP FLOW
- RATE OF CHANGE OF STATIC YIELD STRESS
- MAXIMUM WIDTH OF FORMWORK
- MAXIMUM SIZE OF AGGREGATE
- REINFORCING DENSITY
- MEASURED HYDROSTATIC PRESSURE
- FULL HYDROSTATIC PRESSURE BASED UPON W_cH

OBSERVATIONS

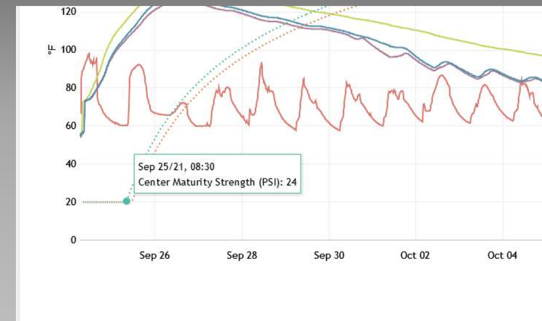
- EXISTING 347 METHODS FOR DETERMINING LATERAL PRESSURE ARE NOT COMPREHENSIVE FROM THE PERSPECTIVE THAT ANY CONDITION OUTSIDE OF SPECIFIED PARAMETERS REVERT TO THE DEFAULT OF $p = W_c h$ - FULL HYDROSTATIC HEAD.
- CEMENTS, ADMIXTURES, POZZOLANS AND SCM'S WHICH HAVE BEEN IN COMMON USE WERE NOT TAKEN INTO CONSIDERATION IN ACI 347-14 CHEMISTRY COEFFICIENTS – CLASS OF FLY ASH, SILICA FUME, TYPES II, IV AND V CEMENTS, VISCOSITY MODIFIERS, WORKABILITY RETENTION ADMIXTURES…
- NONE OF THE MODELS IN THIS PRESENTATION HAVE A PROCESS FOR CHARACTERIZING THE RATE OF VERY EARLY STRENGTH DEVELOPMENT DUE TO EARLY HYDRATION PRODUCTS OF A VERTICAL CONCRETE MIXTURE.
- DISTINGUISHING THIXOTROPIC STRUCTURE FROM THE BRIDGING OF HYDRATION PRODUCTS WITH THE CHARACTERIZATIONS USED FOR SCC LATERAL PRESSURE MODELING IS NOT BEING DONE.
- MANY OF THE MODELS FOR SCC DO NOT TAKE INTO CONSIDERATION TEMPERATURE SECTION 5.2 OF ACI PCR-237/2-21 PROVIDES INFORMATION THAT LOWER TEMPERATURES BOTH INCREASE $P_{(max)}$ AND SLOW THE RATE OF PRESSURE DECAY. MODELING FOR FORMWORK DESIGN IS DONE IN ADVANCE, FOR LONG DURATIONS OF USE AND, THEREFORE, MUST CONSIDER TEMPERATURE VARIATIONS.

SUGGESTIONS AND IDEAS

- FOR CVC INVESTIGATE THE INFLUENCE OF RHEOLOGICAL CHARACTERISTICS – SUCH AS YIELD STRESS VISCOSITY AND THIXOTROPY ON FORMWORK PRESSURE
- COULD CONCRETE MANUFACTURES PROVIDE USEFUL INFORMATION WITHIN VERTICAL CONCRETE MIX DESIGN SUBMITTALS WHICH ARE HELPFUL FOR DETERMINING LATERAL PRESSURE SUCH AS:
  - INITIAL AND FINAL SETTING TIMES OF BINDERS AT THREE TEMPERATURE STATES FOR DETERMING ACTIVATION ENERGY
  - INITIAL AND FINAL SETTING TIMES FOR OF CONCRETE MIXES AS A FUNCTION OF CONCRETE TEMPERATURE
- FOR ALL MODELING, STRUCTURE BUILDING STUDIES AND TEST REPORTING USE A TIME DATUM WHICH CONSISTENTLY STARTS WHEN WATER IS FIRST INTRODUCED
- WITH THE INTRODUCTION OF NEW ADMIXTURES AND ALTERNATE BINDERS AND POZZOLANS, OCCURRING MORE FREQUENTLY CONSIDER DEVELOPING A STANDARDIZED PROCESS FOR THE PHYSICAL CHARICTERIZATION OF CONCRETE FOR ITS LATERAL PRESSURE PROPERTIES. THIS MAY BE A SAFER APPROACH THAN ATTEMPTING TO PROVIDE GENERALIZED DESIGN EXPRESSIONS.
- INVESTIGATE THE USE OF MATURITY TESTING FOR MONITORING STRENGTH DEVELOPMENT DURING PLACEMENT.

USE OF MATURITY TO UNDERSTAND VERY EARLY STRENGTH DEVELOPMENT

PLACEMENT STARTED AT 06:57. ALTHOUGH OUTSIDE OF THE CALIBRATION DATA, STRENGTH IS BEING REPORTED AT THE CENTER SENSOR AT 1.5 HOURS AFTER THE START OF PLACEMENT



TOWER CRANE FOUNDATION MONITORED BY MATURITY SENSORS FOR MAXIMUM TEMPERATURE, SURFACE TO CENTER TEMPERATURE DIFFERENTIAL AND STRENGTH REQUIRED FOR CRANE ERECTION

USE OF MATURITY TO UNDERSTAND VERY EARLY STRENGTH DEVELOPMENT

MATURITY CALIBRATION USED FOR 10-KSI CORE WALL MIX FOR DETERMING WHEN THE SELF-CLIMBING FORM COULD BE RAISED. REPORTING OF COMPRESSIVE STRENGTH FROM LAB CURED CYLINDERS STARTED AT 12 HOURS FOR THIS CALIBRATION. THE GOAL WAS TO IDENTIFY THE MATURITY INDEX REQUIRED FOR 3,500 PSI. THIS WAS USED IN CONJUNCTION WITH ASTM C900, AS VALIDATION, IN THE FIELD.

Calibration Specimens (Compressive Strength)		
Age (days)	Maturity ([0]°C-Hrs)	Compressive Strength (psi)
0.50	271	213
0.67	368	1927
0.75	418	2793
0.79	441	3147
0.92	511	3990
0.92	511	3990
0.92	511	3990
0.92	511	3990
0.92	511	3990
0.92	511	3990

COULD THIS BE DONE, EITHER WITH ASTM C39 OR ASTM C403 TO CORROLATE EARLY DEVELOPMENT OF STRENGTH WITH LATERAL FORMWORK PRESSURE?