TEST OF “**GEOPANEL”** MODULAR PLASTIC FORMWORK SYSTEM ON BEHALF OF CLIENT COMPANY:

GEOPLAST S.p.A.

Grantorto (PD) - via Martiri della Libertà

29/03/2006

REPORT

STUDIO TECNICO I N G. F R A N C E S C O G R A M O L A

Via GUARDI n.5 - CASSOLA (VICENZA) - Tel. 0424/30798

REPORT

1. TEST OF GEOPANEL MODULAR PLASTIC FORMWORK SYSTEM

The undersigned engineer, **Dr. Francesco Gramola**, based in via F. Guardi 5, Cassola (Vicenza), Italy, and registered with the Vicenza Order of Engineers as no. 566, as tasked by the Client, **GEOPLAST S.p.A.**, based in via Martiri della Libertà 6-8, Grantorto (Padova), Italy, has undertaken specified **trials** relating to the **modular plastic formwork system** named **GEOPANEL**.

On the date of 29th March, 2006, at approximately 0900 hours, the following were present at the concrete-mixing plant owned by BETON BRENTA of Grantorto (Padova), Italy, which placed at their disposal the necessary space for the tests, an automated concrete mixer with powered discharge, and the concrete itself:

- **Mr. Pegoraro**, Owner of GEOPLAST S.p.A.;
- Engineer **Dr. Luca Zausa**, Sales Director for GEOPLAST S.p.A.;
- **2 workers** from a construction firm, for the assembly of the forms and to assist in the pouring operations;
- **1 employee of** the firm BETON BRENTA;
- The undersigned engineer, **Dr. Francesco Gramola**, with his own **technical staff,** and the necessary instrumentation (11 deflectometer / analogue centesimal gauges).

GEOPLAST S.p.A. proceeded to assemble the GEOPANEL test formwork in position, without using a crane, or any other lifting equipment. The formwork was arranged as follows [see also the four-page GEOPANEL leaflet from GEOPLAST]:

- 120 cm. x 60 cm. ABS plastic panels, weighing 11 kg. each (in black);
- nylon handles (red);
- lock-nuts for the rolled steel bars (yellow);
- vertical wooden closing panels at the ends of the formwork (yellow);
- metal tubes (red): 2+2 (internal and external), of 121 cm. length each, and with a square section of 50 x 50 x 1.5 mm. both for the lower stringer at the base [these tubes were used to

fix the structure to the floor of the test area, using steel blocks, and prevent movement of the wall during the test], and for the upper stringer installed at a height of about 30 cm.; 8 tubes with a length of 125 cm. and a rectangular section of 50 x 60 x 3 mm. for the external corners, and another 8 tubes of the same length and section for the internal corners.

- 2+2 (two on the outer side of the wall, two on the inner side) inclined metal buttresses of circular metal tubes with a diameter of 5.5 cm., painted red, which did not influence the test, but were installed to guarantee the stability of the structure.

The test formwork therefore resulted in an "L" shaped plan, with the major side of 3.4 metres, while the minor side was of 1.8 metres; the height was of 3 metres; available concrete pouring width was 30 cm.

From the photographs shown below, it is clear that, at intervals of approximately 30 cm., the red-painted rectangular tubes mentioned above secure both the external and internal angles.

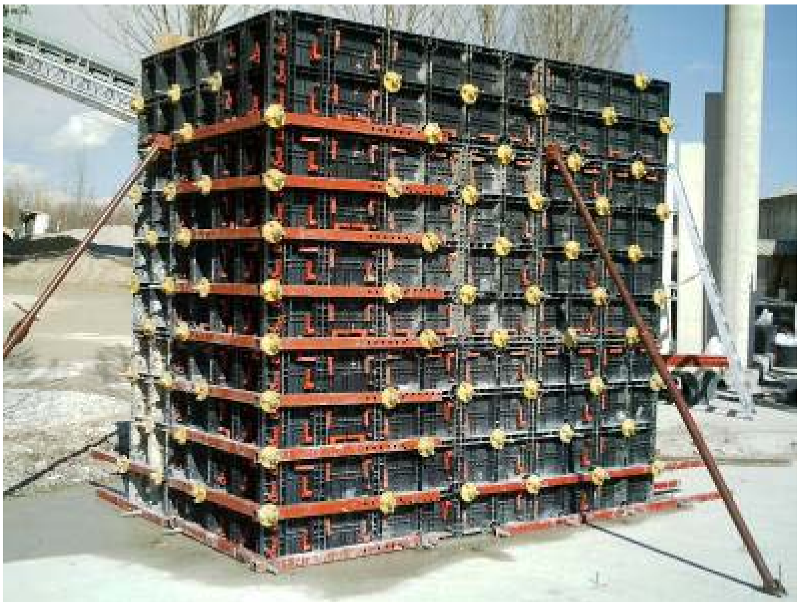


Photo 1: external view of the test form (the short edge faces west, the long edge faces south)

Photo 2: external view of short side (facing west) of the test form.

Photo 3: view inner sides of the test form.

After inspection of the fully assembled forms with all accessories, the measuring instruments for the test were positioned: the instruments were all sited on the sides identified in the photographs as the outer sides of the "L" plan (oriented towards west and south).

The level of the structure was shown to be substantially horizontal, and the form moulds perpendicular to it, as shown by plumb-line measurements.

The following measurement instruments were positioned:

- *11 deflectometers / analogue horizontal centesimal gauges*, supported by suitable metallic mounts independent from the forms (8 gauges on the long side, 3 on the short side); each was numbered, the number written on the base of each instrument.

At 1200 hrs., with an ambient temperature of approximately +20 ºC, all the instruments were calibrated, each with a different starting value, in order to begin the measurement and verification operations. To ensure the greatest accuracy and precision, calibration control and reading was repeated twice for each of the deflectometers [see photos below].

Photo 4: view of southern and western sides, with all the deflectometers already positioned, numbered and calibrated.

Photo 5: view of a positioned, numbered, and calibrated deflectometers.

The firm responsible for the cement mixing provided a concrete with the following technical specifications:

- concrete fluidity: **S4** (i.e. water content ***S*** **–** slump, an important factor in formwork stresses);
- resistance class: $\mathbf{R_{ck}}$ **250**.

At 1215 hrs., with an ambient temperature of approximately +20 ºC, the concrete pour began, requiring a time of about 10 minutes to complete—i.e. to fill the test form to a level of 3 metres, in one continuous pour, with no intermediate pauses. A volume of approximately 4 m^3 of concrete was used.

In order to make the test more demanding, no steel bar or welded grid reinforcement was used within the form.

During these operations, nobody touched, even accidentally, either the test form, or the instruments.

On completion of the concrete pour, all instruments were read.

For greater accuracy and precision, the readings were taken and transcribed twice.

At 1230 hrs., the poured concrete was vibrated. This process took approximately 10 more minutes. Again, during this phase, nobody touched, even accidentally, either the test form or the instruments (the vibrator was manoeuvred from the top of a ladder independent from the structure). The instruments were read again.

As before, for accuracy and precision, the readings were taken and transcribed twice.

After these operations, the GEOPLAST form was kept instrumented until 1515 hrs., when the final readings were taken and transcribed twice.

The ambient temperature during this period had fallen to approximately +19 ºC.

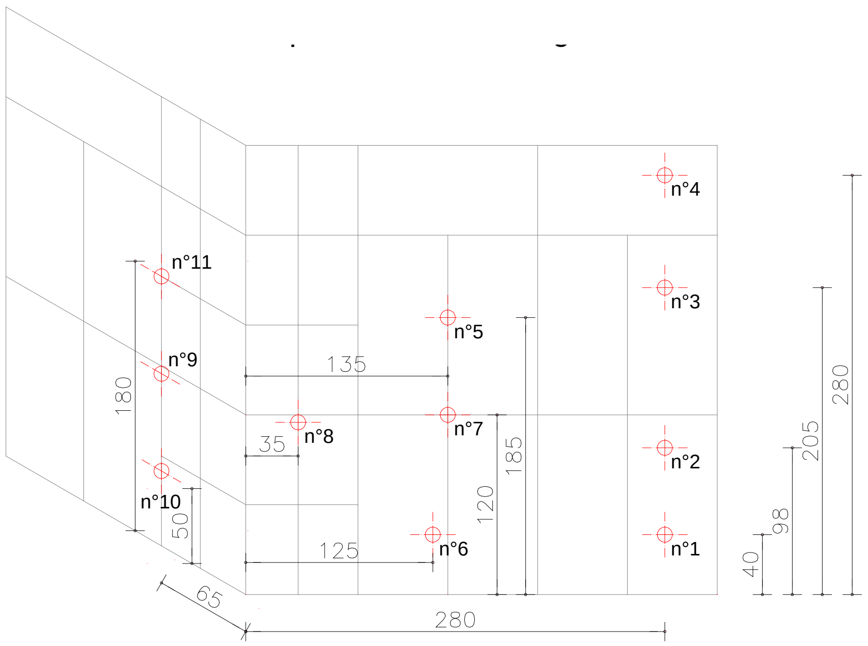
According to the GEOPLAST technicians, the ABS plastic from which the GEOPANEL elements were made has a usable temperature range of between -20ºC and +80ºC, so the test was performed well within these limits.

After the final readings were taken, the instruments were removed.

At around 1530 hrs., the work relating to the testing of the **GEOPANEL** ***modular plastic formwork system*** concluded.

The following shows a plan of the instrument positions, and the table indicating all the data obtained.

Plan of measuring instrument locations



instrument	coordinates		horizontal movement			
n°	x	y	test start 1215 hrs.	end of pour 1225 hrs.	after vibration 1240 hrs.	at rest 1515 hrs.
			t=0min; T=20.0 ºC	t=10min; T=20.0 ºC	t=25min; T=20.0 ºC	t=180min; T=19.0 ºC
	[cm]	[cm]	[mm]	[mm]	[mm]	[mm]
1	280	40	28.32	30.73	31.16	29.73
2	280	98	26.12	29.14	29.60	27.10
3	280	205	22.85	24.00	24.69	23.06
4	280	280	15.12	15.94	16.83	14.53
5	135	185	9.90	6.57	5.79	6.34
6	125	40	27.02	32.64	32.23	29.98
7	135	122	17.93	16.22	15.44	15.19
8	35	115	14.31	17.73	17.71	16.84
9	65	115	8.52	11.35	11.62	11.38
10	65	50	11.02	15.13	15.29	14.65
11	65	177	13.94	14.96	15.19	15.52

instrument	absolute horizontal movement		
n°	test start 1215 hrs.	after vibration 1240 hrs.	at rest 1515 hrs.
	t=10min; T=20.0 C°	t=25min; T=20.0 C°	t=180min; T=19.0 C°
	[mm]	[mm]	[mm]
1	2.41	2.84	1.41
2	3.02	3.48	0.98
3	1.15	1.84	0.21
4	0.82	1.71	-0.59
5	-3.33	-4.11	-3.56
6	5.62	5.21	2.96
7	-1.71	-2.49	-2.74
8	3.42	3.4	2.53
9	2.83	3.1	2.86
10	2.83	3.1	2.86
11	4.11	4.27	3.63

2. **RESULTS AND GENERAL OBSERVATIONS**

Safety

Given the system's **safety** was the primary goal of the test, the results revealed no breakages, either in the connecting handles, or in the individual panels; nor was any dangerous movement of the entire form seen.

This means the GEOPANEL system can be used safely for pouring of concrete walls, even non-reinforced, up to a height of 3 metres, even in presence of angles. This assumes the above-mentioned form components are correctly assembled, braced, and complete with all the necessary connection accessories: handles, nuts and steel bolts, square / rectangular metal tubes.

Concrete

A concrete of type **S4** was chosen to ensure the form was tested to its limits: the more fluid the concrete, the more homogenous the content, and at the end of the pouring phase, the closer one gets to good hydrostatic testing conditions—including evaluations of the pressure to which the GEOPLAST form is subjected.

It is also necessary to consider the fact that the regulations recently adopted in the construction industry, due to the increasing use of metal-reinforced concrete, is causing a wider adoption of ever more fluid concrete mixes, even of the auto-compacting type (known as SCC): all new formwork must be capable of handling such uses.

Finally, the choice of such a fluid concrete mixture allowed the pour to be completed very quickly—just ten minutes—producing a rapid increase in stress, testing the entire formwork structure.

Stresses

Consdering the concrete as a fluid with a specific weight $\gamma = 2400$ kg/m^3; considering the height of the formwork is h = 3 m.; for a form with a unit length (i.e. 1 m.) and assuming, as stated, stress conditions similar to those of a hydrostatic nature, after the vibration phase, we have an overall strain S equal (or very similar) to:

$$S = \frac{1}{2} \cdot h \cdot (\gamma \cdot h) = \frac{1}{2} \cdot 3 \cdot (2400 \cdot 3) = 10800 \text{ kg}$$

This pressure is equivalent to a single force of 10800 kg., applied to one third of the height, i.e. at e height of one metre from the base of the forms.

Regarding the pressure σ, repeating the conditions expressed previously, we have a maximum value, at the base of the forms, equal to:

$$\sigma = \gamma \cdot h = 2400 \cdot 3 = 7200 \text{ kg/ m}^2 .$$

These calculations are in line with the well-known table relating to the pressure of normal concrete mixtures (just poured and therefore mixed with air bubbles and water) and vibrated:

$\mathbf{H_m}$ [m]	$\mathbf{P_m}$ [kg/m²]	
	$\mathbf{C_N}$	$\mathbf{C_V}$
1.25	2150	2950
1.30	2250	3100
1.35	2325	3225
1.40	2400	3350
1.45	2475	3450
1.50	2575	3550
1.55	2675	3675
1.60	2750	3800
1.65	2850	3925
1.70	2925	4050
1.75	3025	4150
1.80	3100	4275
1.85	3200	4400
1.90	3275	4500
1.95	3350	4625
2.00	3400	4750
2.05	3500	4900
2.10	3600	5000
2.15	3700	5100
2.20	3800	5225
2.25	3900	5350
2.30	3975	5475
2.35	4050	5600
2.40	4125	5700
2.45	4225	5850
2.50	4300	5950
2.55	4400	6075
2.60	4500	6200
2.65	4576	6300
2.70	4650	6400
2.75	4725	6500
2.80	4800	6600
2.85	4900	6750
2.90	4975	6850
2.95	5075	7000
3.00	5125	7100

Legend:

H_m [m] = height of the concrete pouring

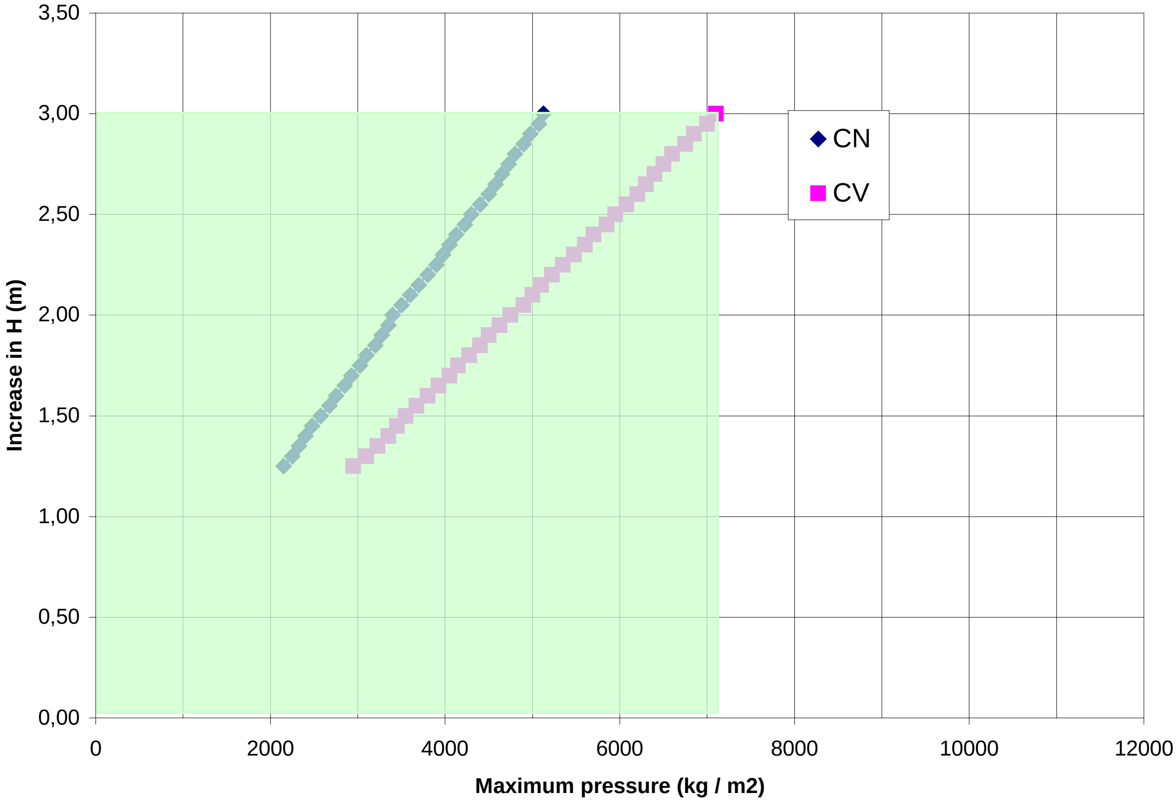
P_m [kg/m^2] = maximum pressure to which the form is subjected

C_N = normal concrete mixture reference (unvibrated)

C_V = vibrated concrete mixture

Increase in H (m)

GRAPH



Note: the disparity (of just 100 kg / m^2) between the theoretical value calculated using hydrostatic laws σ = 7200 kg/m^2, and the value P_m = 7100 kg/m^2 in the table depends on a number of factors, including lithologic and morphologic composition of the inert material (gravel) contained within the concrete conglomerate, and on the friction inevitably generated by the form panels.

In the pouring and mechanical vibration phases, dynamic conditions are generated, with the concrete in motion, differing from the almost hydrostatic state considered earlier.

Therefore, based on indications from the known construction science and technology, we can estimate the dynamic effects induced by the movements of the concrete conglomerate within the form with an increase of 20% respective to the stresses under static conditions, thus giving us:

$$S_d = S \cdot 1{,}2 = 12960 \text{ kg}$$

$$P_{m,d} = P_m \cdot 1{,}2 = 8520 \text{ kg/ m}^2$$

Obviously, this stress increment terminates with the vibration phase and is not seen during pouring of concrete mixes with auto-compaction additives.

It can be reasonably affirmed, therefore, that the GEOPLAST forming system has successfully resisted the forces and pressures calculated above.

Movements

Another aspect of the test requiring further examination is the study of the movement of the forms relative to their initial position.

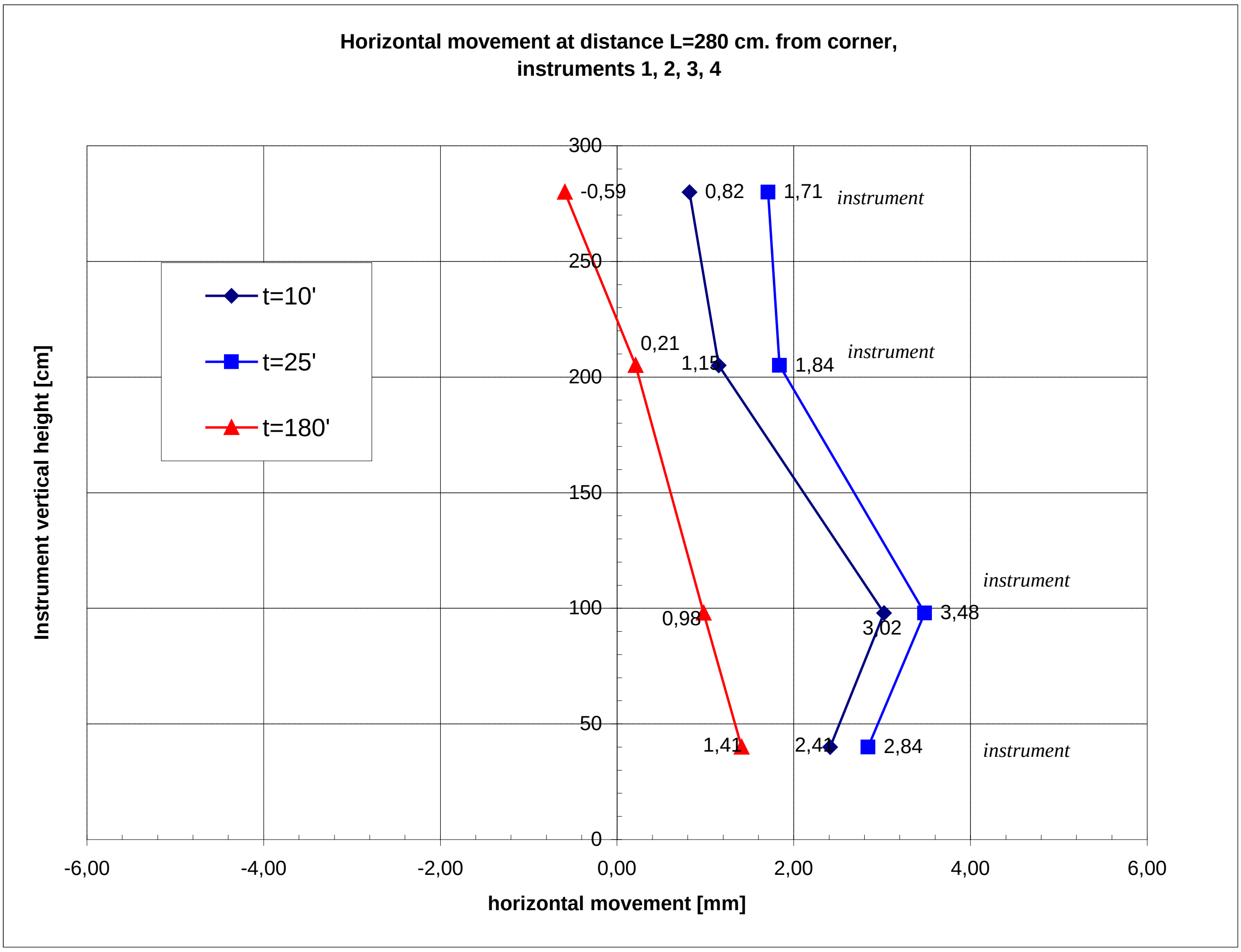
It must first be stressed that, to give an exhaustive opinion on the test and in view of the possibility that GEOPANEL modules may be used in future—e.g. to determine the maximum number of re-uses of the same modules for safety purposes—further research is needed on the stresses placed on the metal outer tubes, on the ABS panels, and the connection accessories.

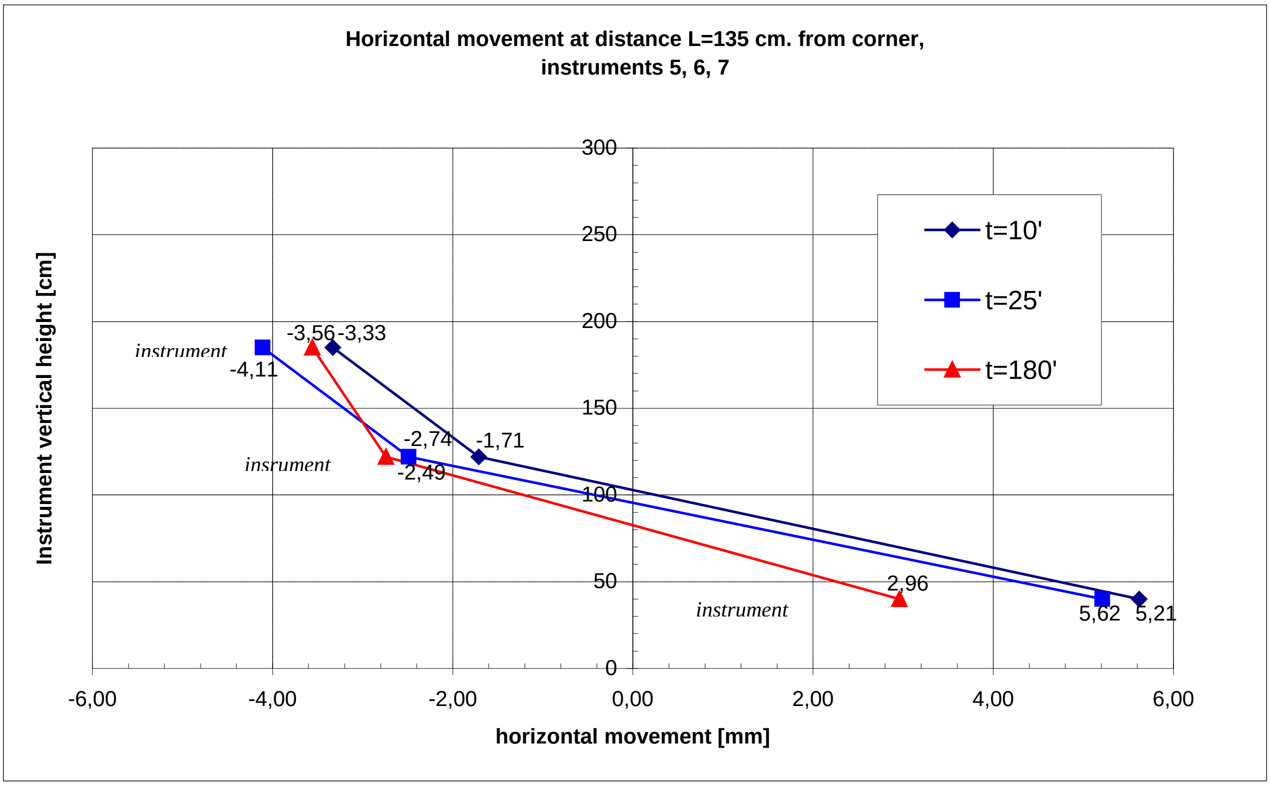
Even so, it is clear that the GEOPLAST system has safely withstood the pressures deriving from the pouring, in a single solution, of a concrete of wall 3 metres in height and 30 cm. wide, with corner.

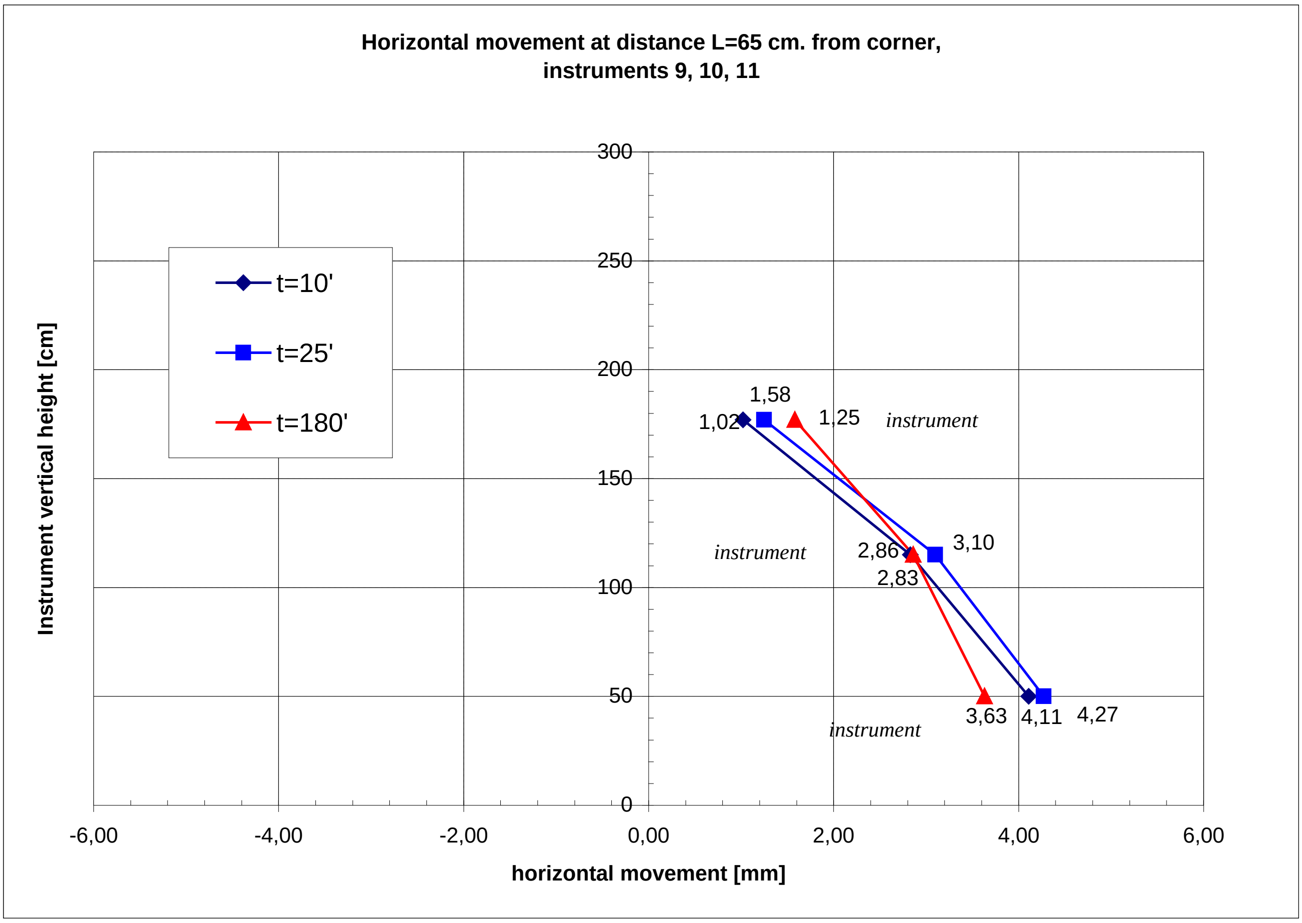
It is also the case that the movement of the form panels, compared with, for example, those of traditional forms, were only slightly greater and, therefore, of the same order of magnitude.

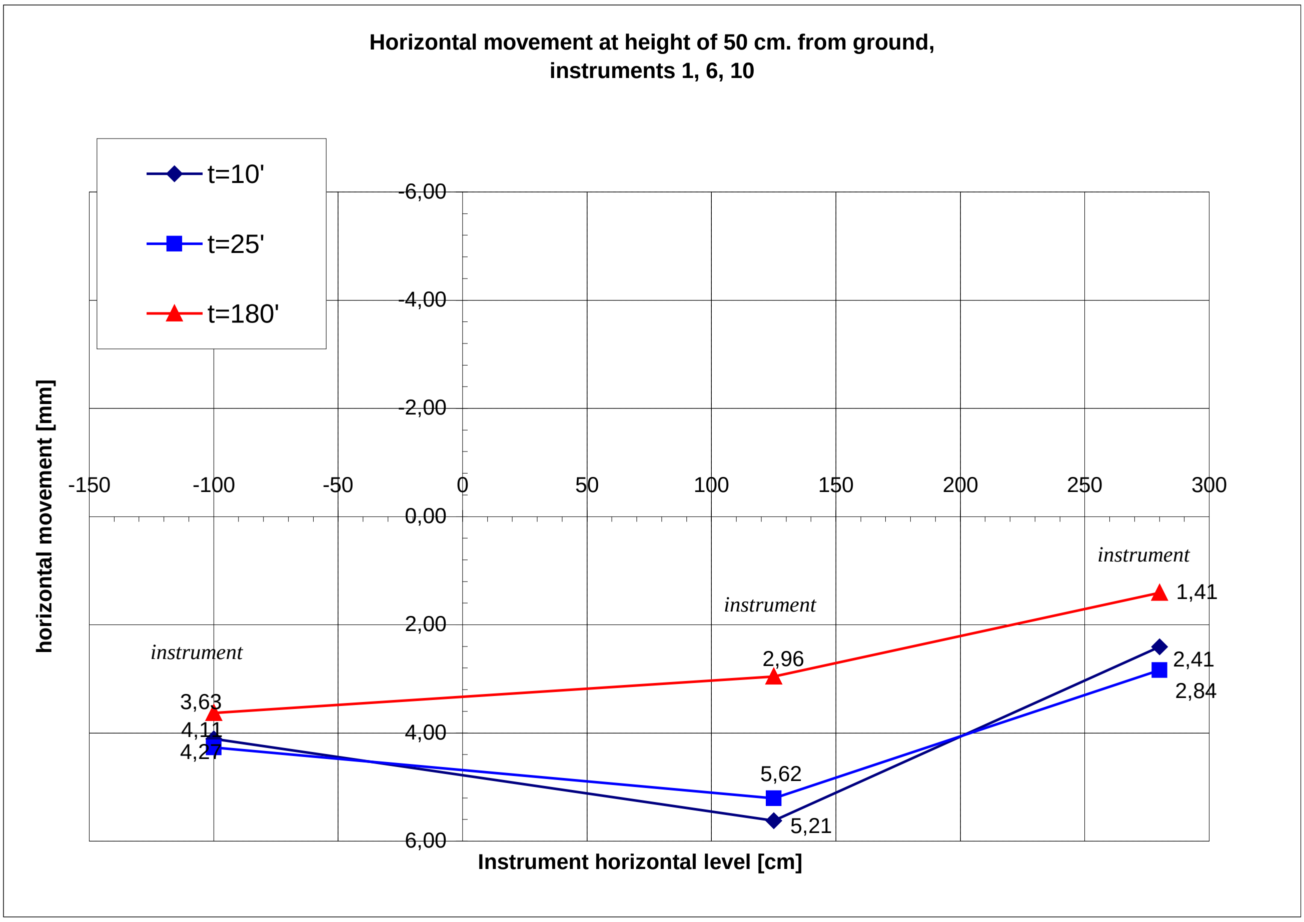
To better evaluate these problems, the disposition of the comparators was chosen such as to supply useful information of movement along both vertical and horizontal axes, (at a height of about a metre, where the pressure readings can be applied as discussed earlier).

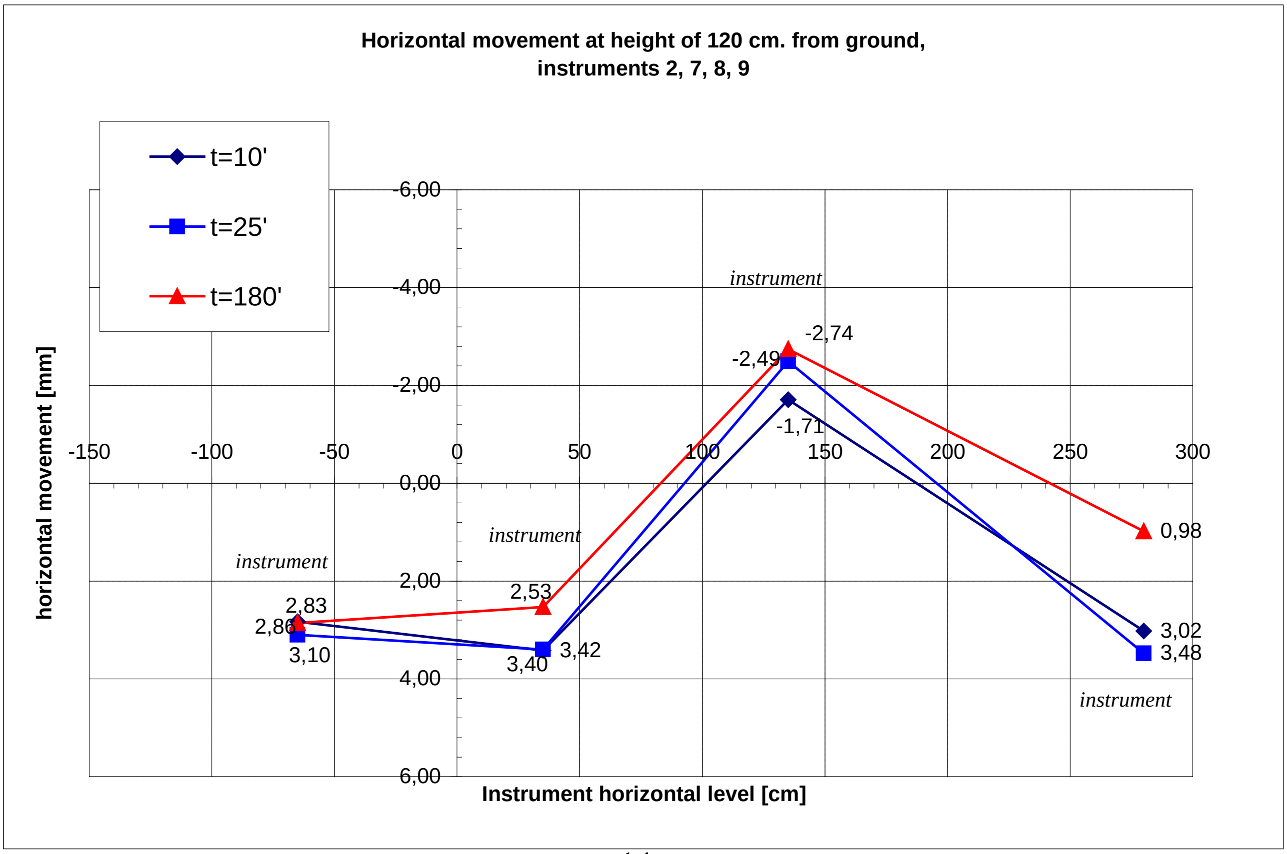
The following graphs show the results obtained.

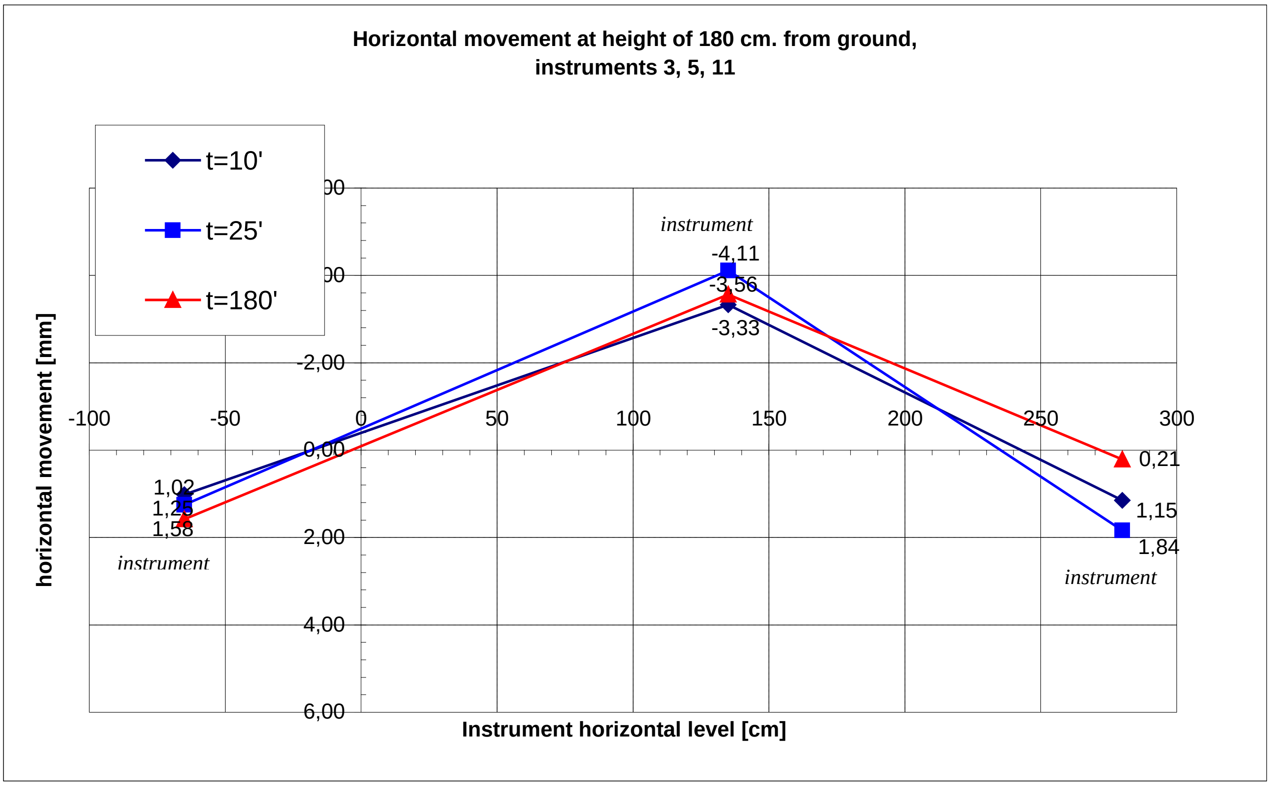



Horizontal movement at distance L=135 cm. from corner,
instruments 5, 6, 7
Instrument vertical height [cm]
horizontal movement [mm]
t=10'
t=25'
t=180'
instrument
insrument
instrument
-3,56
-3,33
-4,11
-2,74
-1,71
-2,49
2,96
5,62
5,21
300
250
200
150
100
50
0
-6,00
-4,00
-2,00
0,00
2,00
4,00
6,00


Horizontal movement at distance L=65 cm. from corner,
instruments 9, 10, 11
Instrument vertical height [cm]
horizontal movement [mm]
t=10'
t=25'
t=180'
instrument
instrument
instrument
1,58
1,02
1,25
2,86
3,10
2,83
3,63
4,11
4,27
300
250
200
150
100
50
0
-6,00
-4,00
-2,00
0,00
2,00
4,00
6,00


Horizontal movement at height of 50 cm. from ground,
instruments 1, 6, 10
t=10'
t=25'
t=180'
horizontal movement [mm]
Instrument horizontal level [cm]
-6,00
-4,00
-2,00
0,00
2,00
4,00
6,00
-150
-100
-50
0
50
100
150
200
250
300
instrument
instrument
instrument
3,63
4,11
4,27
2,96
5,62
5,21
1,41
2,41
2,84


Horizontal movement at height of 120 cm. from ground,
instruments 2, 7, 8, 9
t=10'
t=25'
t=180'
horizontal movement [mm]
Instrument horizontal level [cm]
-6,00
-4,00
-2,00
0,00
2,00
4,00
6,00
-150
-100
-50
0
50
100
150
200
250
300
instrument
instrument
instrument
instrument
2,83
2,86
3,10
2,53
3,40
3,42
-2,74
-2,49
-1,71
0,98
3,02
3,48



One of the first observations we can make is that relating to the fact that the most movement occurs at the end of the pour, a sign that the fluid concrete, without any internal metal reinforcement, has immediately engaged the GEOPANEL formwork; the vibration of the poured concrete resulted in very little change to this situation (see measurements), reinforcing the observation.

The reduction of some of the movements, recorded at 1530 hrs., is not surprising: the concrete mixture used contained a percentage of water, a fraction of which was expelled over time through the gaps between the individual elements of the form panels; furthermore, as noted, the vibration triggers a vertical movement of the air bubbles and water. It must be recorded, too, that the plastic form panels have a good intrinsic elasticity.

[see following photos]

Photo 6: shown from the west side at the end of the test; some slight percolation of the concrete is visible through the gaps in the form panels and onto the ground.

Photo 7: view of a gap that opened at the point where four GEOPANEL elements meet at a corner, with slight fluid percolation.

Photo 8: view of a gap opened between two panel elements, again with slight fluid percolation.

Overall, from our point of view, **the judgement on the measured movements,** especially the final results read after the concrete curing process had begun and no further dimensional variations are expected, **is satisfactory**. Even the dimensional precision of the resulting structure is seen to be similar to that produced using traditional formwork.

APPENDICES

For completeness, a copy of the GEOPANEL informational leaflet is attached, produced by the GEOPLAST company.

Grantorto, 29/03/2006.

Engineer