

St. Astier Mortar Tests : 24-Month Results

September 2000

Enclosed the final results as follows:

Table 1 : Test on NHL/Sand mixes (1:2)

Table 2 : Test on NHL/Sand mixes (1:2.5)

Table 3 : Test on NHL/Sand mixes (1:3)

Table B-1 : Tests on NHL/Putty /Sand blends (NHL 5 blended with Putty @ 10% 30% 50%)

Table B-2 : Tests on NHL/Putty /Sand blends (NHL 3.5 blended with Putty @ 10% 30% 50%)

Table C-1 : Test on Cement/lime/sand mixes (1:1:6 1:2:9)

* The proposed EU norms are conducted on mortars prepared with a binder/sand ratio of approx. 1:1.3. and Standard EU laboratory sand (ISO 679).

* The tests below reflect the performance of mortars made with the same sand but with volumetric mixes that are commonly used.

* Proctors air cured have been stored at constant 15 degrees C and 95% humidity.

* Water addition was made to obtain the same workability on all mortars.

NOTES: Compressive strength in NHL mortars is achieved gradually, allowing for movement. This is due to the lack of cement. In cementitious mixes the hardening is much faster and mostly complete within 28 days.

Elasticity, which is so important to achieve joint free construction, is by far better in NHL mortars than cementitious mixes.

Shrinkage, capillarity and vapour exchange (permeability to air) also show better values than cementitious mixes.

The test on NHL/Putty blends shows the significant performance alteration that takes place. Although this does not signify that these blends cannot be used, we think that the specifier should be aware of the related performance.

The initial set up of these test was done in consultation with Mrs. J. M. Teutonico of English Heritage, Mrs. P. Gibbons of The Scottish Lime Centre, Prof John Ashurst, Douglas Johnston and Arch. Stafford Holmes to whom we are grateful for their co-operation and suggestions.

Mortar Tests

Table 1

TESTS ON PURE NHL MORTARS

Mixing Ratio 1 : 2

Note: performance figures will vary using different sands. For example see figures on NHL 3.5 tested using a 3mm - 0.075 (#6 to #200) well graded common sand (Doyeaux).

	NHL 5		NHL 5		NHL 3.5		NHL 3.5		NHL 2		NHL 2		Norm/method used for test
	Metric		U.S.		Metric		U.S.		Metric		U.S.		
Water content	gr.	225	oz.	7.93	gr.	226	oz.	7.97	gr.	228	oz.	8.04	
Water/binder ratio		0.67		0.67		0.88		0.88		1.07		1.07	
Penetration	mm	8	Inch	5/16	mm	9.5	Inch	3/8	mm	11	Inch	7/16	EN 459-2 Pr. 5.5.3
Set (beginning)	h	4.3		4.3	h	5.3		5.3	h	8 3/4		8 3/4	EN 196.2 P. 6.2
Bulk density (no curing)	kg/m ³	2110	lb/ft ³	132	kg/m ³	2110	lb/ft ³	132	kg/m ³	2100	lb/ft ³	131	EN 459.2 P. 5.8
Air content	%	0		0	%	1.6		1.6	%	2		2	EN 459.2 P. 5.7
Elast. Moduli	Mpa		Psi		Mpa		Psi		Mpa		Psi		
28 days		10800		1566		9010		1306		9025		1308	French Std.
6 months		18000		2610		16250		2356		12600		1827	on one coat plasters
12 months		18510		2684		15280		2216		12515		1815	
24 months		21500		3117		17480		2535		13375		1939	
Flexural Strength	Mpa		Psi		Mpa		Psi		Mpa		Psi		
7 days		0.53		76.85		0.43		62.35		0.28		40.6	as above
28 days		0.9		130.5		0.73		105.85		0.74		107.3	as above
6 months		2.2		319		2.18		316.1		1.28		185.6	
12 months		2.4		348		2.25		326.25		1.3		188.5	
24 months		2.51		363.95		2.6		377		1.41		204.45	
Compressive Strength	Mpa		Psi		Mpa		Psi		Mpa		Psi		
7 days		1.96		284		0.75		109		0.62		90	EN459-2 P. 5.1
28 days		2.2		319		1.88		273		1.48		215	
6 months		7.31		1060		7.1		1029		3.84		557	
12 months		9.28		1346		7.5		1087		4		580	
24 months		10.81		1567		8.63		1251		4.25		616	
Permeability @ complete carb. (gr. of air x m ² x hour x mmHg)		0.55		0.55		0.64		0.64		0.68		1.68	Fr. Std. For one coat plasters
Shrinkage at 28 days	mm.m ¹	0.17	%	17	mm.m ¹	0.59	%	0.059	mm.m ¹	0.75	%	0.075	
Water absorption	l.h.m ²	3	%	3	l.h.m ²	4.5	%	4.5	l.h.m ²	10.5	%	10.5	
Capillarity	g.min	0.88		0.88	g.min	1.18		1.18	g.min	3.05		3.05	

Mortar Tests

Table 2

TESTS ON PURE NHL MORTARS

Mixing Ratio 1 : 2.5

Note: performance figures will vary using different sands. For example see figures on NHL 3.5 tested using a 3mm - 0.075)(#6 to #200) well graded common sand (Doyeaux).

	NHL 5		NHL 5		NHL 3.5		NHL 3.5		NHL 3.5		NHL 3.5		NHL 2		NHL 2		Norm/method used for test
	Metric		U.S.		Metric	U.S.			Metric	Doyeaux sand	U.S.		Metric	U.S.			
Water content	gr.	215	oz.	7.58	gr.	220	oz.	7.76	gr.	250	oz.	8.82	gr.	214	oz.	7.55	
Water/binder ratio		0.79		0.79		1.07		1.07		1.21		1.21		1.27		1.27	
Penetration	mm	7.5	Inch	19/64	mm	9	Inch	23/64	mm	10	Inch	25/64	mm	8.5	Inch	21/64	EN 459-2 Pr. 5.5.3
Set (beginning)	h	3.3		3.3	h	6		6	h	6.15		6.15	h	9		9	EN 196.2 P. 6.2
Bulk density (no curing)	kg/m ³	2115	lb/ft ³	132	kg/m ³	2140	lb/ft ³	134	kg/m ³	1975	lb/ft ³	123	kg/m ³	2080	lb/ft ³	130	EN 459.2 P. 5.8
Air content	%	0		0	%	0		0	%	0		0	%	1		1	EN 459.2 P. 5.7
Elast. Moduli	Mpa		Psi		Mpa		Psi		Mpa		Psi		Mpa		Psi		
28 days		11000		1595		9000		1305		8600		1247		9800		1421	French Std.
6 months		17050		2472		13505		1958		12050		1747		12030		1744	on one coat plasters
12 months		17280		2506		13620		1975						12030		1744	
24 months		18020		2613		13785		1999						12000		1740	
Flexural Strength	Mpa		Psi		Mpa		Psi		Mpa		Psi		Mpa		Psi		
7 days		0.38		55.1		0.31		44.95		0.28		40.6		0.31		44.95	as above
28 days		0.8		116		0.48		69.6		0.45		65.25		0.73		105.85	as above
6 months		1.75		253.75		1.7		246.5		1.3		188.5		1.2		174	
12 months		2.2		319		2.05		297.25						1.25		181.25	
24 months		2.3		333.5		2		290						1.15		166.75	
Compressive Strength	MPa		Psi		MPa		Psi		MPa		Psi		MPa		Psi		
7 days		1		145		0.57		83		0.5		72		0.53		77	EN459-2 P. 5.1
28 days		2		290		1.47		213		1.3		188		1.36		197	
6 months		5.91		857		5.34		774		4.02		583		3		435	
12 months		8.44		1224		5.9		855						2.9		420	
24 months		8.81		1277		6		870						3		435	
Permeability @ complete carb.																	Fr. Std. For
(gr. of air x m2 x hour x mmHg)		0.5		0.5		0.65		0.65						0.71		0.71	one coat plasters
Shrinkage at 28 days	mm.m ¹	0.13	%	0.013	mm.m ¹	0.44	%	0.044	mm.m ¹		%		mm.m ¹	0.6	%	0.06	
Water absorption	l.h.m ²	3.2	%	3.2	l.h.m ²	7.3	%	7.3	l.h.m ²		%		l.h.m ²	12.1	%	12.1	
Capillarity	g.min	2.54		2.54	g.min	4.7		4.7	g.min				g.min	7.84		7.84	

Mortar Tests

Table 3

TESTS ON PURE NHL MORTARS

Mixing Ratio 1 : 3

Note: performance figures will vary using different sands. For example see figures on NHL 3.5 tested using a 3mm - 0.075 (#6 to #200) well graded common sand (Doyeaux).

	NHL 5		NHL 5		NHL 3.5		NHL 3.5		NHL 2		NHL 2		Norm/method used for test
	Metric		U.S.		Metric		U.S.		Metric		U.S.		
Water content	gr.	208	oz.	7.34	gr.	211	oz.	7.44	gr.	206	oz.	7.26	
Water/binder ratio		0.92		0.92		1.23		1.23		1.47		1.47	
Penetration	mm	7	Inch	9/32	mm	8.5	Inch	21/64	mm	9.5	Inch	3/8	EN 459-2 Pr. 5.5.3
Set (beginning)	h	3		3	h	6		6	h	9.3		9.3	EN 196.2 P. 6.2
Bulk density (no curing)	kg/m ³	2105	lb/ft ³	131	kg/m ³	2110	lb/ft ³	131	kg/m ³	2100	lb/ft ³	131	EN 459.2 P. 5.8
Air content	%	0		0	%	3		3	%	2		2	EN 459.2 P. 5.7
Elast. Moduli	Mpa		Psi		Mpa		Psi		Mpa		Psi		
28 days		10000		1450		8970		1301		9000		1305	French Std.
6 months		16900		2450		12450		1805		11800		1711	on one coat plasters
12 months		16150		2342		13150		1907		11900		1725	
24 months		17540		2543		13670		1982		11750		1704	
Flexural Strength	Mpa		Psi		Mpa		Psi		Mpa		Psi		
7 days		0.4		58		0.28		40.6		0.25		36.25	as above
28 days		0.66		95.7		0.65		94.25		0.72		104.4	as above
6 months		1.55		224.75		1.38		200.1		1.08		156.6	
12 months		1.8		261		1.5		217.5		1.05		152.25	
24 months		2.05		297.25		1.53		221.85		1.05		152.25	
Compressive Strength	MPa		Psi		MPa		Psi		MPa		Psi		
7 days		0.88		128		0.53		77		0.47		68	EN459-2 P. 5.1
28 days		1.5		217		1.34		194		1.25		181	
6 months		5.31		770		3.94		571		2.88		418	
12 months		6.5		942		3.9		565		2.9		420	
24 months		7.8		1131		3.97		576		2.75		399	
Permeability @ complete carb. (gr. of air x m2 x hour x mmHg)		0.52		0.52		0.72		0.72		0.71		0.71	Fr. Std. For one coat plasters
Shrinkage at 28 days	mm.m ⁻¹	0.15	%	0.015	mm.m ⁻¹	0.25	%	0.025	mm.m ⁻¹	0.51	%	0.051	
Water absorption	l.h.m ⁻²	5.5	%	5.5	l.h.m ⁻²	9.4	%	9.4	l.h.m ⁻²	15.4	%	15.4	
Capillarity	g.min	4.61		4.61	g.min	6.3		6.3	g.min	8.7		8.7	

Mortar Tests

Table B-1

Blend ratio	NHL / Putty Lime Blends												Norm/method used for test
	NHL 5/Putty/Sand				NHL 5/Putty/Sand				0.5/0.5/3				
	0.9/0.1/3		U.S.		0.7/0.3/3		U.S.		0.5/0.5/3		U.S.		
	Metric			Metric		Metric		Metric					
Water/binder ratio	gr	1.2		1.2	gr	1.07		1.07	gr	1.03		1.03	
Penetration	mm	7	Inch	9/32	mm	10	Inch	25/64	mm	11	Inch	7/16	EN459-2 P. 5.5.3
Set (beginning)	h	3.5		3.5	h	5.25		5.25	h	9.5		9.5	EN 196-2 P. 5.8
Bulk density (no curing)	kg/m ³	2105	lb/ft ³	131	kg/m ³	2040	lb/ft ³	127	kg/m ³	2030	lb/ft ³	127	EN 459-2 P. 5.8
Air content	%	0		0	%	0		0	%	3		3	EN 459-2 P. 5.7
Elast. Moduli	Mpa		Psi		Mpa		Psi		Mpa		Psi		
28 days		11000		1595		10020		1453		8000		1160	French Std.
6 months		16000		2320		14000		2030		13000		1885	on one coat
12 months		16510		2394		14320		2076		13020		1888	plasters
24 months		16500		2392		13950		2023		13220		1917	
Flexural Strength	N/mm ²		Psi		N/mm ²		Psi		N/mm ²		Psi		
7 days		0.4		58		0.35		50.75		0.32		46.4	As above
28 days		0.67		97.15		0.65		94.25		0.45		65.25	
6 months		1.15		166.75		1.13		163.85		0.83		120.35	
12 months		1.75		257.75		1.15		166.75		0.85		123.25	
24 months		1.55		224.75		1.2		174		0.8		116	
Compressive Strength	N/mm ²		Psi		N/mm ²		Psi		N/mm ²		Psi		
7 days		0.82		119		0.66		96		0.42		61	EN 459-2 P. 5.1
28 days		1.4		203		1.1		159		0.6		87	
6 months		4.8		696		3.95		573		2.97		431	
12 months		5.3		768		4.1		594		2.8		406	
24 months		5.25		761		431		625		2.85		413	
Permeability at complete Carb. (vapour exchange) (gr of air x m ² x hour x mmHg)		0.6		0.06		0.59		0.059		0.63		0.063	Fr. Std.
Shrinkage at 28 days	mm.m ¹	0.25	%	0.25	mm.m ¹	0.6	%	0.6	mm.m ¹	0.84	%	0.84	One coat
Water absorption at compl. Carbonation	l.h.m ²	10		10	l.h.m ²	12.3		12.3	l.h.m ²	18		18	plasters
Capillarity at compl. Carbonation	g.min	9.5		9.5	g.min	10.2		10.2	g.min	13.75		13.75	

NOTE : NHL 2 blend tests were not conducted as this product should not be blended.

Mortar Tests

Table B-2

NHL / Putty Lime Blends NHL 3.5/Putty/Sand

Blend ratio	0.9/0.1/3				0.7/0.3/3				0.5/0.5/3				Norm/method used for test
	Metric		U.S.		Metric		U.S.		Metric		U.S.		
Water/binder ratio	gr	1.04		1.04	gr	1		1	gr	0.95		0.95	
Penetration	mm	8	Inch	5/16	mm	12	Inch	15./32	mm	13	Inch	33/64	EN459-2 P. 5.5.3
Set (beginning)	h	6.5		6.5	h	8.5		8.5	h	10		10	EN 196-2 P. 5.8
Bulk density (no curing)	kg/m ³	2070	lb/ft ³	129	kg/m ³	2040	lb/ft ³	127	kg/m ³	2020	lb/ft ³	126	EN 459-2 P. 5.8
Air content	%	3		3	%	4		4	%	6		6	EN 459-2 P. 5.7
Elast. Moduli	Mpa		Psi		Mpa		Psi		Mpa		Psi		
28 days		8400		1218		8050		1167		7510		1089	French Std.
6 months		13200		1914		12600		1827		11000		1595	on one coat
12 months		13410		1944		12900		1870		11050		1602	plasters
24 months		14520		2105		13010		1886		10850		1573	
Flexural Strength	N/mm ²		Psi		N/mm ²		Psi		N/mm ²		Psi		
7 days		0.38		55.1		0.5		72.5		0.26		37.7	As above
28 days		0.6		87		0.52		75.4		0.38		55.1	
6 months		1.33		192.85		1.05		152.25		0.65		94.25	
12 months		1.5		217.5		1.2		174		0.8		116	
24 months		1.56		226.2		1.26		182.7		0.84		121.8	
Compressive Strength	N/mm ²		Psi		N/mm ²		Psi		N/mm ²		Psi		
7 days		0.76		110		0.76		110		0.22		32	EN 459-2 P. 5.1
28 days		1.3		188		1.1		159		0.75		109	
6 months		3.9		565		3.63		526		2		290	
12 months		4.8		696		4.4		638		3.75		544	
24 months		4.75		689		4.55		660		2.65		384	
Permeability at complete Carb. (vapour exchange) (gr of air x m2 x hour x mmHg)		0.69		0.069		0.71		0.071		0.68		0.068	Fr. Std.
Shrinkage at 28 days	mm.m ¹	0.35	%	0.35	mm.m ¹	0.67	%	0.67	mm.m ¹	0.89	%	0.89	One coat
Water absorption at compl. Carbonation	l.h.m ²	11.2		11.2	l.h.m ²	15.6		15.6	l.h.m ²	19.3		19.3	plasters
Capillarity at compl. Carbonation	g.min	4.41		4.41	g.min	8.72		8.72	g.min	12.94		12.94	

NOTE : NHL 2 blend tests were not conducted as this product should not be blended.

Mortar Tests

Table C-1

CEMENT/HYDRATED LIME/SAND

Blends

	1 : 1 : 6			1 : 2 : 9			Norm/method used for test
	Metric		U.S.	Metric		U.S.	
Water content	gr.	200		200	gr.	200	
Water/binder ratio		0.72		0.72		0.65	
Penetration	mm	7	Inch	9/32	mm	7	Inch
Set (beginning)	h	1.3		1.3	h	1	
Bulk density (no curing)	kg/m³	2100	lb/ft³	131	kg/m³	2100	lb/ft³
Air content	%	0		0	%	0	
Elast. Moduli	Mpa		Psi		Mpa		Psi
28 days		16200		2349		15595	
6 months		22010		3191		19300	
12 months		22210		3220		19700	
24 months		22150		3212		19650	
Flexural Strength	N/mm²		Psi		N/mm²		Psi
7 days		2.05		297		1.65	
28 days		1.95		283		1.55	
6 months		2.1		304		1.5	
12 months		2.2		319		1.7	
24 months		2.2		319		1.75	
Compressive Strength	N/mm²		Psi		N/mm²		Psi
7 days		5.02		728		4.96	
28 days		7.7		1116		5.56	
6 months		8.1		1174		5.75	
12 months		8.7		1261		6.05	
24 months		8.5		1232		5.95	
Permeability (Vapour exch. Gr of air x m2 x hour x mmHg)		0.23		0.23		0.25	
Shrinkage at 28 days	mm.m¹	0.63	%	0.063	mm.m¹	0.42	%
Water absorption at compl. Carbonation	l.h.m²	0.23		0.23	l.h.m²	0.25	
Capilarity at compl. Carbonation	g.min	1.08		1.08	g.min	6.86	

EN459-2 p. 5.5.3
EN459-2 P. 6.2
EN459-2 P.5.8
EN459-2 P. 5.7
French Std. For
one coat plasters
As above

EN459-2 P. 5.1

At complete carb
French Std. For
one coat plasters