IV–8. Masonry Veneer Walls

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ABSTRACT

In Sweden the main production of clay bricks and sandline bricks is used for facade-covering. The walls will usually be erected with an external wythe insulated from the back-up wall and anchored to this by metal ties.

A couple of investigations have been performed concerning the following items: A) Measuring of movements under various conditions, diurnal as well as annual movements due to fluctuations in temperature and moisture; B) Tests with wall ties of different dimensions and steel grades subjected to repeated flexural deformation, resulting in stresses in excess of the yield strength of the material.

As a result of these investigations a simple rule has been established when designing wall ties fixed at one or both ends. On the other side a system of movable anchorages has been developed to avoid bending stresses due to movements between the outer and the inner part of the walls. The ties are intended to be attached to various back-up wall systems, such as masonry, concrete-, steel- or wood-structures. Some of these wall ties have been prescribed as Swedish Standard.

GENERAL

Masonry veneer walls (external walls with a half-brick outer leaf insulated from the back-up structure) are very common in Sweden. The main production of bricks and sandlime bricks is used for this type of walls. Figure 1.

Some tests have been performed to find out the behaviour of the walls under various climatic conditions and some job has also been done to develop suitable methods for anchoring the veneer walls to different back-up structures.

INVESTIGATION OF MOVEMENTS

Solitary movements are of comparatively little interest. Shrinkage and creep of a back-up concrete structure have often advanced far towards its final level when the masonry veneer wall is erected. Solitary movement of the masonry also takes place within a couple of hours.

Repeated movements are of greater interest. The outer leaf follows the changes of outside temperature quite rapidly. The masonry is also affected by the sun radiation which can give a high surface temperature when using dark facing bricks. The inside air temperature and consequently that of the back-up wall is, however, fairly constant. On the other hand, humidity changes are often obvious both outside and inside and are contributing to expansion differences between the back-up structure and the masonry veneer.

Long-range tests, performed in Södertälje (south-west from Stockholm, latitude 59°) during the period 1971–1974, concerning temperature and movement of veneer walls of clay brick as well as sandlime brick, have provided an extensive basis for evaluation. The tests have been supplemented with a comparative laboratory test the purpose to point out the connection between the masonry colour and the increase in temperature due to sun radiation. The results from the temperature investigation of the facades and of specially erected test surfaces are accounted for in Tables 1 and 2.

In order to be able to transfer the experiences to areas of other climatic conditions than those of Södertälje, the test results have been used to show the difference between the temperature of masonry and the air temperature.

Concerning anchoring of masonry veneer walls and especially the ability of the wall ties to resist repeated bending, the short-range movements are significant. For other purposes, e.g. when evaluating expansion joints, long-range movements are of greater interest.

Short-Range Movements

The maximum diurnal movement noted for the brick veneer wall is 0.18 mm/m and for that of sandlime brick 0.28 mm/m. Movements of that magnitude may occur during the whole period March until October. The magnitude of the average daily movement is interesting when evaluating the risk of bending fatigue failure. For the two wall types examined the average movement is appr. 40% of the maximum daily value.

The measuring has given a thermal expansion coefficient of $6 \cdot 10^{-6}$ per °C for brick masonry and $10 \cdot 10^{-6}$ per °C for sandlime brick masonry.

Long-Range Movements

Figure 2 shows the highest and the lowest temperatures noted for each month and the corresponding position changes of the masonry veneer top, in both cases related to a concrete back-up structure. The total difference of movement between veneer wall and back-up wall measured during the year corresponds to appr. 0.25 mm/m for brick and 0.5 mm/m for sandlime brick. It should, however, be noticed that the measurements have been executed during some fairly mild winters. The obvious poor conformity between temperature and movement indicates that the moisture changes play an important role.

The outside relative humidity which may affect the front wall, has its peak value during autumn and winter while the lowest values are noted for May and June. The inside relative humidity which may affect the back-up structure, decreases during the winter and then increases when the heating season is over, i.e. generally in May. This implies a tendency of the outer leaf to lower itself in relation to the back-up wall during the early part of the summer and then to rise again when the winter is approaching.

A diagram on the influence of the moisture and temperature expansions is shown in Figure 3. As can be seen, the moisture changes have the effect to moderate the total amplitude during the year.

The measurements indicate that the brick facade has a movement caused by moisture of 0.18 o/oo in relation to the concrete back-up wall, corresponding to an anticipated temperature difference of appr. 30 °C in the masonry. For sandlime brick this movement is 0.35 o/oo or a corresponding temperature difference of appr. 35 °C.

INVESTIGATION OF WALL TIES

Wall ties of various materials used to anchor masonry veneer walls may in some cases be subjected to flexural deformations resulting in stresses in excess of the yield strength of the material. There is a danger that repeated movements may result in fatigue failure.

In view of the lack of information as to the fatigue properties of slender stainless wire on plastic bending it was considered that this matter should be investigated under conditions which may be assumed to apply to wall ties. A test was performed using a number of different steel grades, but with main emphasis on grade SIS 2343 (chromium, nickel, molybdenium), cold-drawn ($\sigma_{0.2} \approx 800$ MPa) as well as annealed ($\sigma_{0.2} \approx 300$ MPa) wire of different dimensions.

In spite of the plastic nature of the movements it has been convenient to express the "load effect" by the stress formula applicable to elastic flexural movement, viz

$$\sigma_f = 3\,E\,d\,\delta / l^2$$

where d is the diameter of wire, δ the deflection and l the free length of the wall tie fixed at both ends. This fictive quantity, termed σ_f, has been related to the number of flexural movements prior to failure.

The curves in the diagram, Figure 4, delineate the range inside which bending failure occurred for grade SIS 2343. The lower boundary of this range for all grades tested, with the exception of copper wire, is denoted by the discontinuous line in the diagram.

As regards the danger of fatigue due to bending of the wall ties the maximum daily variation is of greater interest than the larger annual movements. Looking at the diagram it will be possible to estimate the risk of fatigue failure.

For example:

A brick veneer wall exposed to variations of temperature and moisture for a long time (e.g. 100 years). The wall is anchored by ø 4 mm ties, grade SIS 2343, fixed at both ends and with a free length of 100 mm.

$n = 100 \times 365 = 36\,500$ cycles

$\sigma_f \approx 1300$ MPa (diagram, Figure 4)

$$\delta \leq \sigma_f\, l^2/3\,E\,d = \frac{1300 \cdot 100^2}{3 \cdot 210\,000 \cdot 4} = 5 \text{ mm}$$

Thus at an average deflection of 5 mm there will probably be no failure, but the safety factor of coarse has to be considered.

According to the Swedish Building Code the permissible deflection due to temperature is limited to

$$\delta = 2 \cdot 10^{-3} \cdot l^2 / d$$

for a tie fixed at both ends and double the value with one end fixed and the other hinged. The quantity δ implies the maximum daily thermal deflection which, according to the Code, shall be calculated at 0.25 mm/m for masonry of brick and 0.3 mm/m for sandlime brick.

In this example the formula will give

$$\delta = 2 \cdot 10^{-3} \cdot 100^2 / 4 = 5 \text{ mm},$$

a value approximately corresponding to the maximum thermal movement of a six-storey brick wall (20 × 0.25 = 5 mm).

The investigation, Chapter B, indicates that the average deflection is about 40% of the maximum value for the two wall types mentioned and in this fact the safety factor is to be found.

SURVEY OF ANCHORAGES (Swedish Standard)

In Sweden quite some work has been laid down to develop better methods for anchoring masonry veneer walls. There have been two reasons for this. Firstly, to avoid bending stress due to movements between the outer and the inner parts of the wall. Secondly, to find a more rational system of anchoring to facilitate the brick-laying.

A group of the Swedish Building Standard Institution has developed such a system which has been prescribed as Swedish Standard. The anchorages are designed to be attached to various back-up walls, such as masonry-, concrete-, steel- or wood-structures.

The most frequent component is a hook with a curl in its end. The counterpart is a frame of wire or a staple, attached to the back-up structure. The frame is higher than one layer plus the expected movement, so there is no need of accuracy when fixing it to the back-up wall. The staples, designed for wood-structures, are rifled to get a better pull-out-strength, when the wood shrinks in drying.

The Swedish Standard includes two types of material for ties, grade SIS 2343 (stainless steel) and SIS 1300 (galvanised carbon steel). According to the Swedish Building Code anchorages of stainless steel shall be used for veneer walls exceeding a height of 6 mtrs.

Figure 5 is a survey of standardized anchorages (fixed and movable), including useful information for designing, e.g. maximum loads permissible.

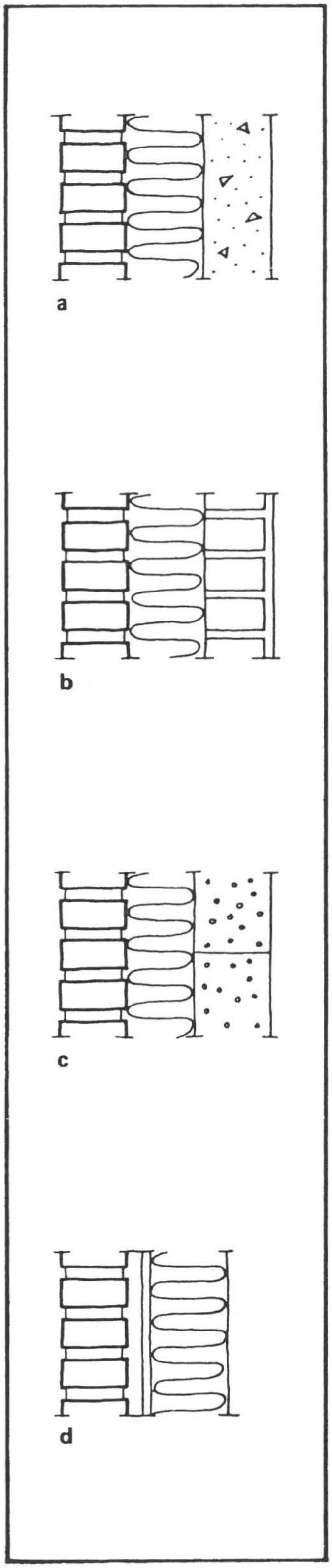


Figure 1. Types of masonry veneer walls

TABLE 1—Maximum temperatures

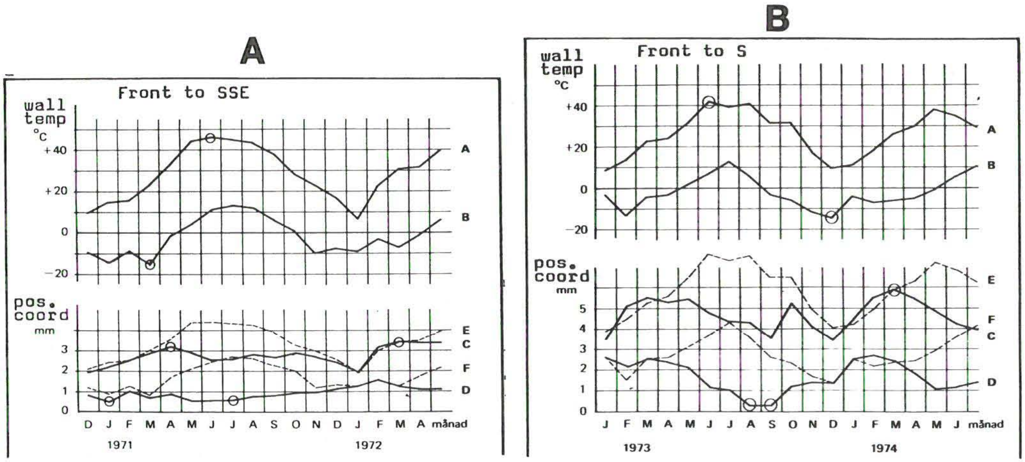
Type of wall		Temperature in wall center, °C
dark brown brick	test surface	+ 47.5
normally red brick	facade	+ 46.0
white sandlime brick	facade	+ 42.0
white sandlime brick (new)	test surface	+ 37.0

TABLE 2—Temperature variations

Type of wall		Max. daily variation Δt, °C
dark brown brick	test surface	33.0
normally red brick	facade	31.5
white sandlime brick	facade	28.5
white sandlime brick (new)	test surface	23.5

TABLE 3—Difference between masonry temperature and air temperature

Type of wall		Max. difference Δt, °C
dark brown brick	test surface	24.5
normally red brick	facade	24.5
white sandlime brick	facade	16.0
white sandlime brick (new)	test surface	13.0



Key to figure 2A & B

A. max wall temperature
B. min wall temperature
C. max level, measured
D. min level, measured
E. max level, expected
F. min level, expected due to temp

Figure 2. A) Brick veneer wall. Height 10.6 mtrs. Max and min temperature and position observation of each month.
B) Sandlime brick veneer wall. Height 11.5 mtrs. Max and min temperature and position observation of each month

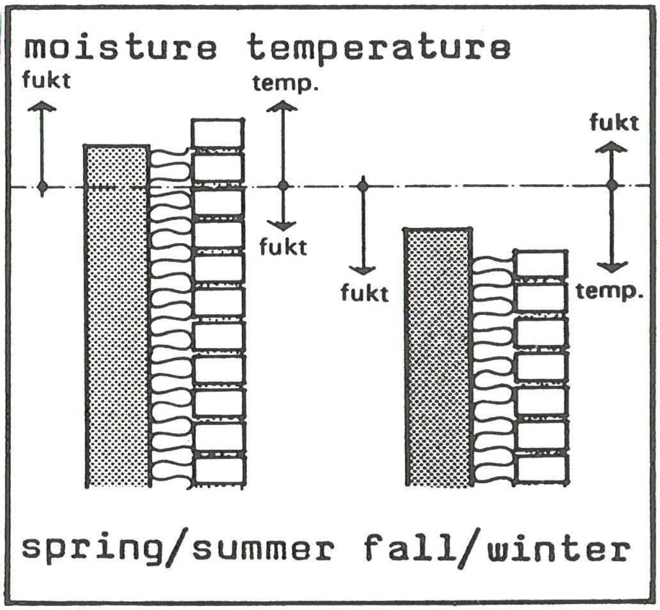


Figure 3. Differences in movements between veneer wall and back-up structure caused by moisture and temperature

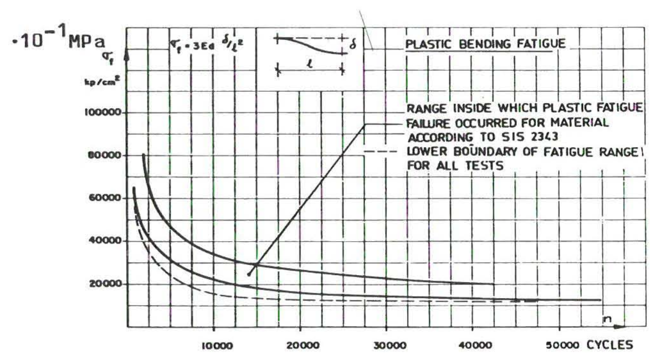


Figure 4. Plastic bending fatigue test

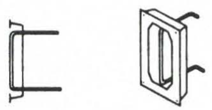
Type		Anchorages according to Swedish Standard		Back-up structure	Material	Dimensions, mm	Perm. loads, kN + = tension - = compression		Fixing
1		Kramla med öppen ögla "Hook" with open loop		Stainl.	Rostfritt	Ø4 L =50, 75, 100, 125, 150 Ø5 L =175, 200, 225	+0,50 −0,50		Kramlan placeras vinkelrätt mot murverkets plan och muras in minst 40 mm Min insert depth 40 mm
				Galv.st.	Förzinkat (får användas upp till höjd 6 m)	Ø5 L =50, 75, 100, 125, 150 =175, 200, 225	+0,25 −0,25		
a	Counterparts to type 1	Bygel med ingjutningsdosa Frame with plastic box		Betong Concrete	Rostfritt	Ø4 h=100	0,30		Plastdosan ansluts till formen på sådant sätt att betong inte tränger in i dosan
						Ø4 h=130	0,25		
						Ø5 h=100	0,60		
						Ø5 h=130	0,50		
b		Bygel med fastdon Frame with screws		Stål Steel	Rostfritt	Ø4 h=100	0,30		Bygeln monteras med gängformade skruv i förborrade hål. Anslutningen kan anordnas med skruvriktningen vinkelrät mot eller parallell med muren
						Ø4 h=130	0,25		
						Ø5 h=100	0,60		
						Ø5 h=130	0,50		
c		Bygel Frame		Lättbetong-murverk (porbetong, lättklinker) Masonry of lightweight concrete	Rostfritt	Ø4 h=100	0,30		Bygelns vinkelbockade skänklar slås in i murblockets stötyta (ändyta). Bygeln tillåts skjuta ut högst 20 mm utanför murlivet
						Ø4 h=130	0,25		
						Ø5 h=100	0,60		
						Ø5 h=130	0,50		
						Ø5 h=100	0,45	Lättbetongkval.-grupp400och450	
						Ø5 h=130	0,45		
d		Märla (förbockad ankarspik) Staple		Lättbetong (porbetong, lättklinker) Lightweight concrete	Hårddraget och förzinkat (får användas upp till höjd 6 m)	Ø4 L=100	0,30		Märlan slås in i c:a 45° riktning mot ytan med skänklarna i samma vertikala plan. Märlan tillåts skjuta ut högst 15 mm utanför vägglivet
						Ø4 L=100	0,20	Lättbetongkval.-grupp400och450	
e		Märla (räfflad pa bada sidor) Staple with rifles		Trä Wood	Rostfritt Hårddraget och förzinkat (får användas upp till höjd 6 m)	Ø4 L=75, 95 h=25, 40	0,30		Märlan slås in vinkelrätt mot väggytan så att inträngningsdjupet i trästommen blir minst 50 mm
2		Z-kramla Z - tie		Murverk Masonry	Rostfritt	Ø4 L=150, 175 Ø5 L=200, 225, 250, 275, 300	−0,70 ℓ ≤ 170 −0,45 ℓ ≤ 220 +0,70 ℓ ≤ 300	Se även tabell 24:43 i SBN 75	Kramlan placeras vinkelrätt mot murverkets plan och muras in minst 40 mm Min insert depth 40 mm
					Förzinkat (får användas upp till höjd 6 m)	Ø4 L=150,175 Ø5 L=200, 225, 250, 275, 300	−0,30 ℓ ≤ 220 +0,70 ℓ ≤ 300		
3		Murkamspik (rullgängad spik) Rifled nail		Trä Wood	Rostfritt	Ø4 L=100, 125, 145, 175	+0,50 −0,50		Spiken slås in vinkelrätt mot väggytan så att inträngningsdjupet i trästommen blir minst 50 mm, samt muras in minst 40 mm i murverket

Figure 5.