Feature

Recent developments in providing houses of masonry construction in South Africa

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Introduction

One of the major challenges facing the new South Africa is that of providing shelter for its burgeoning urban population. Current estimates of housing needs vary considerably because of the differences in assumptions on which they are based. One of the most authoritative commissions in recent years, the de Loor Commission, concluded that the existing housing backlog is 1 299 000 units and the number of shelters to be put up for new family formations amounts to 198 000 units p.a. Thus in order to provide for new family formation and to eradicate the existing backlog over 10 years, approximately 300 000 units have to be provided p.a.

The rate of housing delivery in recent years has hovered around 40 000 units[1]. Currently, the Government is planning for the delivery of 150 000 units p.a. in terms of its recently launched subsidy scheme. Whatever the figure, there is a dire need for housing which the industry needs to deliver at a considerably higher rate than it has done in the past.

The national housing subsidy scheme is a capital subsidy of varying value according to income, ranging from R5000 to R15 000 (£700 to £2100) in four increments. The subsidy is applied to the servicing of land and the creation of stock. It may also, in certain circumstances, be applied to previously owned stock. The maximum subsidy amount of R15 000 is generally used to cover the cost of servicing the site; little residual is available for top structures. The bulk of subsidies approved to date have been in this category, where beneficiaries earn less than R800 a month and have little to contribute for more substantial units. A recent report, published in March 1996[2], indicates that approximately 15 000 houses have been delivered through the scheme, some 275 000 subsidies had been approved, and approximately 500 000 sites were in the delivery process chain. The report also estimates that the sale of housing units costing less than R150 000 has risen in 2 years by 47% from the 1993 base to 83 000 p.a.

Currently, the MANTAG (Minimum Agreement Norms and Technical Advisory Guide) criteria for the acceptability of low-cost affordable housing (single-storey detached dwellings) are: [3,4]

- behaviour in fire
- structural strength and stability
- thermal performance
- weathertightness
- protection against harmful substances
- provision for ventilation and natural lighting

The MANTAG criteria may be regarded as minimum norms and are based on an evaluation of fitness-for-purpose, i.e. on health and safety aspects. Wallis[3], however, lists the following criteria as being beyond minimum performance:

- privacy (both visual and acoustic)
- comfort and habitability
- aesthetic satisfaction
- value for money
- marketability
- security
- status

Masonry construction does meet both the MANTAG and 'beyond minimum performance' requirements. It is also extremely versatile and cost effective in its application. As a result, masonry construction is the most popular form of house construction in South Africa and is frequently used as the benchmark against which all other forms of house construction are measured.

Masonry is also an important construction material from an employment perspective. It is particularly effective in employment generation and permits significant quantities of work to be performed by local communities for which housing is to be provided. Tables 1 and 2, which Watermeyer & Band[1] presented in a recent report for the National Housing Forum, demonstrate masonry's performance in this regard. Its potential for employment generation can be further increased by means of onsite manufacture of masonry units by labour-intensive manufacturing methods.

Quality concerns

Although masonry as a material may be regarded as being fit for purpose in housing, substandard workmanship, poor construction practices and injudicious selection of its constituent materials may result in structural strength and stability being impaired and in loss of weathertightness.

Poor quality masonry housing, particularly at the lower end of the market, has, in the past, had a very serious impact on the housing industry. In some areas, consumers have expressed their dissatisfaction by boycotting bond repayments. Banks have responded by refusing to fund low-cost housing in certain areas.

The Joint Structural Division of the IStructE/SAICE in a recent newsletter[5] reported that, historically, masonry houses have been designed by rule-of-thumb or by reference to tables of empirical design. Few houses have collapsed, but many have cracked. Cracking may be attributed to either foundation movement or substandard workmanship, poor construction practices and the injudicious selection and use of materials, or a combination thereof.

TABLE 1 – Manhours employment generated in the construction of masonry and non-masonry houses

Construction type	Number of manhours			Number of manhours for equivalent masonry houses		
	Off-site materials manufacture	Site labour	Total	Off-site materials manufacture	Site labour	Total
Timber (SALMA)	300	1180	1480	200	1700	1900
Precast concrete panels and posts (Blitz)	150	210	360	120	1120	1240
Steel frame with 110mm brick infill panels (Belaton)	330	880	1210	160	1400	1560

TABLE 2 – Employment generated/unit of expenditure in various types of house construction

Construction type	Cost in Rands		Cost/manhour (Rand/manhour)	
	Non-masonry	Masonry Equivalent	Non-masonry	Masonry Equivalent
Timber (SALMA)	47 200	46 100	32	24
Precast concrete panels and posts (Blitz)	16 000	20 300	44	16
Steel frame with 110 mm brick infill panels (Belaton)	28 400	30 800	23	20

TABLE 3 – Residential site class designations

Typical founding material	Character of founding material	Expected range of total soil movement (mm)	Assumed differential movement (% of total)	Site class
Rock (excluding mud rocks which may exhibit swelling to some depth)	Stable	Negligible	–	R
Fine-grained soils with moderate to very high plasticity (clays, silty clays, clayey silts and sand clays)	Expansive soil	<7.5 <7.5-15 15-30 >30	50% 50% 50% 50%	H H1 H2 H3
Silty sands, sands, sandy and gravelly soils	Compressible and potentially collapsible soils	<5 5-10 >10	75% 75% 75%	C C1 C2
Fine-grained soils (clayey silts and clayey sands of low plasticity), sands, sandy and gravelly soils	Compressible soil	<10 10-20 >20	50% 50% 50%	S S1 S2
Contaminated soils Controlled fill Dolomitic areas Landslip Land fill Marshy areas Mine subsidence Mine waste fill Reclaimed areas Very soft silt/silty clays Uncontrolled fill	Variable	Variable		P

TABLE 4 – Foundation design, building procedures and precautionary measures for single-storey residential buildings founded on expansive soil horizons

Site class	Estimated total heave (mm)	Construction type	Foundation design and building procedures (Expected damage limited to category 1)
H	<7.5	Normal	• Normal construction (strip footing or slab-on-the-ground foundations) • Site drainage and service/plumbing precautions recommended.
H1	7.5-15	Modified normal	• Lightly reinforced strip footings • Articulation joints at all internal/external doors and openings • Light reinforcement in masonry • Site drainage and plumbing/service precautions
		Soil raft	• Remove all or part of expansive horizon to 1.0m beyond the perimeter of the structure and replace with inert backfill compacted to 93% MOD AASHTO density at –1% to + 2% of optimum moisture content • Normal construction with lightly reinforced strip footings and light reinforcement in masonry if residual movements are <7.5mm, or construction type appropriate to residual movements • Site drainage and plumbing/service precautions
H2	15-30	Stiffened or cellular raft	• Stiffened of cellular raft with articulation joints or solid lightly reinforced masonry • Site drainage and plumbing/service precautions
		Piled construction	• Piled foundations with suspended floor slabs with or without ground beams • Site drainage and plumbing/service precautions
		Split construction	• Combination of reinforced brickwork/blockwork and full movement joints • Suspended floors or fabric reinforced ground slabs acting independently from the structure • Site drainage and plumbing/service precautions
		Soil raft	• As for H1
H3	>30	Stiffened or cellular raft	• As for H2
		Piled construction	• As for H2
		Soil raft	• As for H1

National Building Regulations

The National Building Regulations include functional regulations which set out the requirements for the performance of a building or element thereof without specifying the materials, dimensions, or methods of construction. Rules have been formulated to facilitate the design of traditional forms of construction and are published in SABS 0400[6]. Compliance with these rules is deemed-to-satisfy the regulations. Insofar as construction is concerned, no deemed-to-satisfy rules are provided, and the regulation simply requires that 'all workmanship in the erection of any building shall be in accordance with sound building practice.'

Engineers in South Africa, when designing masonry structures on a rational basis, using the current structural Codes of Practice, are often frustrated by the fact that, in many instances, a more economical design than that emanating from the empirical 'deemed-to-satisfy' rules cannot be achieved. This is particularly evident in instances where walls are exposed to high wind loads or earth loads. These discrepancies may be attributed to inconsistencies and a lack of harmony between 'deemed-to-satisfy' rules and structural Codes of Practice, examples being the following:[7]

(1) The permissible dimensions of walls given in the deemed-to-satisfy rules are often greater than those permitted in terms of the limiting dimensions given in the Code of Practice for structural masonry (SABS 0164).

(2) The tabulated deemed-to-satisfy wall panel does not restrict the size of openings and permits the tabulated wall dimensions to be applied to external cladding on buildings up to 25 m in height in any wind terrain category. By comparison, BS 5628 *Code of practice for the use of masonry: Part 3: Materials and components, design and workmanship* offers rules for design, based on structural calculations, tabulates maximum wall areas for walls in buildings of four storeys and less, situated in wind terrain categories 3 and 4, which have unsupported window openings less than 10% of the wall area.

(3) The deemed-to-satisfy rules do not differentiate between units of brick size and block size with regard to the lateral strength of wall panels, free-standing walls and retaining walls. The structural Codes of Practice, on the other hand, indicate that the maximum flexural strength of brick-size unit panels can be up to twice that of block-size unit panels.

The deemed-to-satisfy rules also inadequately address the size of 110mm external wall panels in buildings. The rules provide for maximum unsupported lengths of 6.0m, which is clearly excessive, particularly in the case of gable ends, and has, in some instances, led to the collapse of walls in houses. There is considerable demand in South Africa for the use of thinner walls to be permitted in the more arid parts of South Africa, in order to effect economies.

Insofar as foundations are concerned, the National Building Regulations require that 'the foundation of any building shall be designed to safely transmit all the loads from such buildings to the ground'. The deemed-to-satisfy rules which are provided in SABS 0400 are valid only where the supporting soil is not a 'heaving soil or shrinkable clay, or soil with a collapsible fabric.'

Expansive, collapsible and compressible soil horizons are wide spread over most parts of South Africa. Horizons with potentially collapsible fabrics are commonly encountered in the Free State north of Bloemfontein stretching to the Vaal River. Expansive soils, on the other hand, are more widely distributed across South Africa and have been reported to occur in most parts of the country with the exception of the Little Karoo, the extreme northern portion of the Northern Cape, the far northern regions of the Northern Province, and the extreme eastern regions of the Mpumalanga Province. The areas most affected by expansive soils include the Free State gold fields, the North West and the Gauteng Province – some of the most densely populated areas in South Africa. Accordingly, these deemed-to-satisfy rules have limited application. The regulations furthermore do not contain any formal procedures to establish founding conditions. Local authorities may, however, in areas which are known to have problem soils, require that a competent person be appointed to design house foundations.

The Joint Structural Division's Code of Practice

The Joint Structural Division, as a contribution to the Government of National Unity's Reconstruction & Development Programme, drafted a Code of Practice[10] dealing with masonry substructures and superstructures in single-storey buildings. The substructure portion of the Code is based primarily on a publication by Watermeyer & Tromp[8], a manual published by the Ennerdale Local Committee[9], and the Standards Association of Australia's Code of Practice for residential slabs and footings (AS 2870).

The purpose of the Code of Practice is to provide, primarily in respect of single-storey masonry buildings:

- a procedure to classify founding horizons according to their potential to cause foundations movements in terms of building practice
- general design principles with a view to accommodating expected foundation movements in the design of foundations and of the superstructure in a manner which will prevent distortions and cracking in excess of the predetermined level of damage
- guidance on the location and design of articulated joints
- simple rules to facilitate construction on founding horizons exhibiting a low range of movement; and
- simple rules relating to structural aspects of superstructures which, if adopted, will result in buildings having adequate strength and structural integrity

The Code of Practice requires sites to be classified in accordance with Table 3 and foundation designs and building procedures to be in accordance with Tables 4 and 5, so as to achieve minor damage (categories 0 to 2 expected damage) as set out in Table 6. Guidance is offered in an appendix to the Code in respect of the selection of allowable deflection ratios when designing stiffened rafts in respect of category 1 expected damage (see Table 7). Design rules are provided for houses founded on class C, C1, H, H1, S, S1 and R sites.

The Code of Practice also contains design rules governing masonry superstructures. A series of tables provide rules to permit the sizing of wall panels which :

- are supported on two or three sides
- contain no opening or openings which may be either greater or less than 15% of the wall area
- contain tied control/articulation joints
- incorporate gable ends
- support roofs

Tables are also provided to facilitate the design-by-rule of foundation walls, roof anchors, reinforced masonry lintels (bedjoint reinforced and reinforced hollow unit) and composite lintels.

The tables relating to wall panel size were derived from a yieldline analysis of a range of wall panel configurations. The remaining tables were derived by applying the current South African structural Codes of Practice to the particular element under consideration. The Code differentiates between solid and hollow unit construction and provides solutions for a range of panels which cover cavity wall construction (leaf thickness of 90 and 110mm) and single-leaf wall construction for nominal wall thicknesses between 90 and 220mm. (See Tables 8 and 9.) The design of wall panels in accordance with these tables will result in walls having shorter unsupported panel lengths than would have been the case had such walls been designed using the deemed-to-satisfy tables contained in SABS 0400 (see Table 10).

The Code of Practice requires that vertical control joints be provided in houses to accommodate movements induced by environmental factors such as (see Table 11):

TABLE 5 – Foundation design, building procedures and precautionary measures for single-storey residential buildings founded on horizons subject to consolidation and collapse settlement or a combination of both

Site class	Estimated total settlement (mm)	Construction type	Foundation design and building procedures (Expected damage limited to category 1)
C (S)	<7.5 (<10)	Normal	● Normal construction (strip footing or slab-on-the-ground foundations) ● Good site drainage
C1 (S1)	7.5-15 (10-20)	Modified normal	● Reinforced strip footings ● Articulation joints at some internal and all external doors ● Light reinforcement in masonry ● Site drainage and service/plumbing precautions ● Foundation pressure not to exceed 50 kPa
		Compaction of *in situ* soils below individual footings	● Remove *in situ* material below foundations to a depth and width of 1.5 × the foundation width or to a compacted horizon and replace with material compacted to 93% MOD AASHTO density at –1% to +2% of optimum moisture content ● Normal construction with lightly reinforced strip foundation and light reinforcement in masonry
		Deep strip foundations	● Normal construction with drainage requirements ● Founding on a competent horizon below the problem horizon
		Soil raft	● Remove *in situ* material to 1.0m beyond perimeter of building to a depth of 1.5 × the widest foundation or to a compacted horizon and replace with material compacted to 93% MOD AASHTO density at –1% to +2% of optimum moisture content ● Normal construction with lightly reinforced strip footings and light reinforcement in masonry
C2 (S2)	>15 (>20)	Stiffened strip footings, stiffened or cellular raft	● Stiffened strip footings or stiffened or cellular raft with articulation joints or solid lightly reinforced masonry ● Bearing pressure not to exceed to 50 kPa ● Fabric reinforcement in floor slabs ● Site drainage and service/plumbing precautions
		Deep strip foundations	● As for C1 (S1) but with fabric reinforcement in floor slabs
		Compaction of *in situ* below individual footings	● As for C1 (S1)
		Piled or pier foundations	● Reinforced concrete ground beams or solid slabs on piled or pier foundations ● Ground slabs with fabric reinforcement ● Good site drainage
		Soil raft	● As for C1 (S1)

TABLE 6 – Classification of damage with reference to masonry walls

Description of damage in terms of ease of repair and typical effects	Approximate maximum crack width in walls (mm)	Category and degree of expected damage
Minor damage – categories 0 to 2		
Hairline cracks less than about 0.25mm width are classed as negligible.	<0.25	0 Negligible
Fine internal cracks which can easily be treated during normal decoration. Cracks rarely visible in external masonry.	<1 (isolated, localised)	1 Very slight
Internal cracks easily filled. Redecoration probably required. Recurrent cracks can be masked by suitable linings. Cracks not necessarily visible externally. Doors and windows may stick slightly.	<5	2 Slight
Significant damage – categories 3 to 5		
Cracks can be repaired and possibly a small amount of masonry may have to be replaced. Articulation joints may have to be cut in some of the walls. Doors and windows sticking. Rigid service pipes may fracture, Weather-tightness often impaired. Up to 10mm gap between ceiling cornices and walls.	5 to 15 (or a number of smaller cracks (3 to 5) in one group))	3 Moderate
Extensive repair work which includes breaking out and replacing sections of walls, especially over doors and windows, cutting of articulation joints in walls, and the construction of moisture trenches and apron slabs around the structure, or the jacking of foundations depending on the type of soil movement. Window and door frames distorted, floor sloping noticeably. Walls leaning or bulging noticeably, some loss of bearing in beams. Service pipes probably disrupted. Up to 20mm gap between ceiling cornices and walls.	15 to 25 (depending also on a number of cracks in a group)	4 Severe
Major repair work required, involving partial rebuilding and the above mentioned repair techniques. Beams loose bearing, walls tilt badly and require shoring. Windows broken and distorted. Danger of instability.	Usually greater than 25 (depending also on number of cracks in a group)	5 Very severe

- changes in temperature
- changes in moisture content
- carbonation
- moisture movement (wetting and drying)
- moisture expansion

Although the Code of Practice applies primarily to single-storey residential buildings it may be applied to double-storey residential buildings provided that the total soil movements for the various site class designations are adjusted to take into account the substantial increase in bearing pressures, and particular attention is paid to the detailing of masonry and to its stability should articulation or full movement joints be provided. Double-storey house construction forms a relatively small percentage of house construction in South Africa; hence no attempt was made to frame the Code of Practice around such construction.

The National Home-Builders Registration Council's Warrantee Scheme

The late Minister of Housing, Mr Joe Slovo, together with the Housing Consumer Protection Trust, engaged in lengthy discussions relating to consumer protection and the home-building industry. The Department of Housing's White Paper, the Botshabelo Accord, and the Government's Record of Understanding with the banks, identified the need for a Home-Builders' Warranty Scheme. Accordingly, the Council for Construction in South Africa (COCOSA) were called upon to establish a steering committee comprising all stakeholders in the home-building and associated industries. The steering committee, chaired by COCOSA, worked for 15 months to establish the principles and the details of a scheme which was workshopped around the country to determine contractors' opinions at grassroot level. A revised scheme was then produced and approved by all of the constituent stakeholders. On 5 June 1995, the National Home-Builders Registration Council (NHBRC), a private, non-Government, non-profit company, was officially launched.

The Home-Builders Warranty Scheme is not an insurance scheme. Rather, it is a method whereby, if a registered contractor refuses, or is unable, to honour his contractual or warranty obligations, the NHBRC may step in and provide support to the consumer. In terms of the scheme, contractors are to provide the consumer with an undertaking to rectify any structural defect occurring within 5 years of the residence being occupied that has been caused by non-compliance with the NHBRC's technical standards. The contractor is, at the same time, required to register with the NHBRC, to undertake to adhere to its Code of Conduct and Rules and to construct units in accordance with the NHBRC's technical requirements.

The financial institutions, in turn (effective from 1 February 1996), grant mortgage finance, for residential units of R250 000 and less, only to registered contractors who operate within the ambit of the scheme. (In the near future, it is intended that the scheme will be extended to all housing.) Enrolment of the housing units with the NHBRC prior to construction is a prerequisite. Currently, the warranty premium amounts to 1.3% of the total contract value of the enrolled unit. The scheme is, accordingly, an essential component in the housing delivery process where mortgage lending finance is involved.

Standards and guidelines have been developed to provide rules to enable valid defects to be interpreted on a non-compliance basis and, hence, warranty cover to be established. The standards and guidelines frame performance-orientated design and construction requirements around the assumption that defects in housing can be minimised, if not eliminated, if those responsible for the design and construction of dwelling units:

- adopt design practices and specifications that provide satisfactory performance
- use materials, products and building systems that are suited for their intended purpose

TABLE 7 – Allowable deflection ratios in respect of category 1 expected damage

Type of masonry	Allowable deflection ratio ((Δ/L)	
	Unreinforced	Lightly reinforced
Hogging movements		
Articulated masonry		
– plastered	1 : 800	1 : 600
– face	1 : 650	1 : 500
Full masonry		
– plastered	1 : 2000	1 : 1250
– face	1 : 1500	1 : 1000
Sagging movements		
Articulated masonry		
– plastered	1 : 500	1 : 500
– face	1 : 350	1 : 300
Full masonry		
– plastered	1 : 1000	1 : 500
– face	1 : 500	1 : 300

- ensure that all work is carried out in a proper, neat and workmanlike manner

The standards and guidelines transform the performance-orientated statements, in the first instance, into a set of requirements and, in the second instance, into a set of rules which, if followed, will ensure compliance with these requirements. The focus of the standards and guidelines is on structural strength and stability, and weathertightness. They do, however, also deal with protection against harmful substances and behaviour in fire, insofar as they relate to the structural stability of the housing unit.

The NHBRC design requirements can be met by:

- adopting certain prescribed rules; or
- preparing a rational design based on engineering principles; or
- obtaining Agrément certification from Agrément South Africa

Similarly, the NHBRC construction requirements can be met by complying with:

- the relevant portions of a construction standard covering the construction of elements designed using the design-by-rule approach; or
- the standards and specifications referred to in the rational design; or
- the relevant requirements set out in the Agrément certification documentation

The design-by-rule approach is directed towards traditional (standard) construction practices involving the use of masonry walling and timber roofing. Both the design rules and construction requirements associated with this form of construction are based on practices which have been shown to be satisfactory and acceptable over a period of time. The rational design and Agrément certification approaches permit the use of innovative and non-standardised forms of construction. In this manner, all forms of construction may be included in the scheme should they comply with the NHBRC requirements[12].

The committee responsible for developing the standards and guidelines examined the approaches adopted by other nations, when formulating the approach which was finally adopted[12]. Of particular interest was the experience of the United Kingdom where the National House-Building Council (NHBC) introduced a 10-year major structural defects warranty scheme in 1965, which, by 1973, had some 1.6M dwellings under warranty. In 1976, figures were published in respect of a 2-year period ending in June 1976 for some 1082 claims. These statistics are summarised in Table 12. An examination of the statistics reveals that 76.2% of claims, representing 90.4% of the total cost, related to substructure (foundation) issues. Chapman *et al.* [11], based on their interpretation of these statistics, reported that there was some tentative evidence to suggest about one failure in five was an engineered foundation, either piling, raft or deep strip, and considered that these failures arose mainly from inadequate site appreciation and ground investigation and insufficient control on site, rather than from design errors *per se*.

The standards and guidelines committee, at the outset, recognised the need to address prob-

TABLE 8 – Unsupported wall panel lengths derived from a design-by-rule approach

Nominal wall thickness (mm)	Maximum unsupported panel length	
	SAICE/IStructE Code of Practice (m)	SABS 0400 (m)
Solid units		
90	2.3-3.2	not permitted
90-90	4.0-5.5	8.0
110	3.0-4.5	6.0
110-110	5.0-7.0	9.0
140	4.5-7.0	6.0
190	6.5-8.0	8.0
220	8.0-9.0	9.0
Hollow units		
90	2.0-2.9	not permitted
90-90	3.5-5.0	8.0
110	2.7-3.5	6.0
110-110	4.0-6.0	9.0
140	3.3-5.5	6.0
190	4.5-7.5	8.0

TABLE 9 – Maximum dimensions for external wall panels supported on both sides

Nominal wall thickness (mm)	Wall type	Panel A				Panel B				Panel C			
		No openings				Openings ≤15% wall area				Openings >15% wall area			
		L	H	L	H	L	H	L	H	L	H	L	H
Solid units													
90	single leaf	3.2	2.4	2.8	3.4	2.7	2.4	2.5	3.4	2.7	2.4	2.3	3.4
90-90	cavity	5.5	2.7	5.5	3.9	5.5	2.7	5.0	3.9	5.5	2.4	4.5	3.9
110	single leaf	4.5	2.7	4.0	3.6	4.0	2.7	3.5	3.6	3.5	2.7	3.0	3.6
110-110	cavity	7.0	3.3	6.0	4.4	7.0	2.4	5.5	4.4	6.5	2.4	5.0	4.4
140	single leaf	7.0	3.3	6.0	4.3	6.5	2.4	5.2	4.3	6.0	2.7	5.0	4.3
190	collar jointed	8.0	4.6	8.0	4.6	8.0	4.6	8.0	4.6	8.0	4.0	7.5	4.6
220	collar jointed	9.0	4.6	9.0	4.6	9.0	4.6	9.0	4.6	9.0	4.6	9.0	4.6
Hollow units													
90	single leaf	2.8	2.4	2.5	3.4	–	–	–	–	–	–	–	–
90-90	cavity	5.0	2.7	4.5	3.9	4.5	2.4	4.0	3.9	4.0	2.7	3.5	3.9
110	single leaf	3.5	2.4	3.3	3.6	3.0	2.4	2.8	3.6	3.0	2.4	2.8	3.6
110-110	cavity	6.0	2.4	5.0	4.2	5.0	2.4	4.2	4.2	4.5	2.7	4.2	4.2
140	single leaf	5.5	2.4	4.5	4.2	4.5	2.7	4.0	4.2	4.2	2.4	3.7	4.2
190	single leaf	7.5	2.7	6.0	4.4	6.5	2.4	5.0	4.6	6.0	2.7	4.8	4.4

TABLE 10 – Maximum unsupported panel length of 2.6m high external wall panel supporting a free-standing isosceles triangle gable or portion thereof

Nominal wall thickness (mm)	Wall type	No openings					With openings				
		Slope (°)									
		11	15	17	22	26	11	15	17	22	26
Solid units											
90	single leaf	2.8	2.7	2.6	2.6	2.6	2.4	2.4	2.4	2.4	2.4
90-90	cavity	5.5	5.5	5.5	5.0	5.0	4.5	4.5	4.0	4.0	4.0
110	single leaf	4.5	4.5	4.5	4.0	4.0	4.0	4.0	3.5	3.5	3.5
110-110	cavity	7.0	7.0	6.5	6.0	6.0	6.0	5.5	5.5	5.0	5.0
140	single leaf	6.5	6.0	5.5	5.5	5.5	5.0	5.0	4.5	4.5	4.5
190	collar jointed	8.0	8.0	8.0	8.0	8.0	8.0	7.5	7.5	7.0	6.5
220	collar jointed	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Hollow units											
90	single leaf	2.5	2.5	2.5	2.5	2.5	2.1	2.1	2.1	2.0	2.0
90-90	cavity	4.5	4.5	4.0	4.0	4.0	3.5	3.5	3.5	3.5	3.5
110	single leaf	3.5	3.5	3.3	3.3	3.0	3.0	3.0	2.8	2.7	2.7
110-110	cavity	5.5	5.5	5.0	5.0	5.0	4.5	4.5	4.0	4.0	4.0
140	single leaf	4.5	4.5	4.5	4.0	4.0	4.0	3.5	3.5	3.3	3.3
190	single leaf	6.0	5.5	5.5	5.0	5.0	5.0	5.0	5.0	4.5	4.5

TABLE 11 – Maximum spacing of vertical control joints in walls

Unit type	Moisture expansion	Approximate spacing of 8 to 12mm joints (m)	
		Free-standing wall	Buildings
Unreinforced masonry			
Burnt clay	<0.05	16	18
	0.05-0.10	10	14
	0.10-0.20	6	10
Calcium silicate	–	7.5-9.0	9
Concrete	–	5.0-7.0	8
Masonry with bedjoint reinforcement			
Burnt clay	<0.05	16	18
	0.05-0.10	12	16
	0.10-0.20	8	12
Calcium silicate	–	10	12
Concrete	–	10	12

TABLE 12 – Analysis of valid major structural defect claims paid in the United Kingdom over a 2-year period ending June 1976

Subject of claims	Frequency (%)	Cost (%)
Substructure (infill)		
– Subsoil shrinkage	2.2	2.3
– soft ground beneath	2.0	2.9
– use of chemically active shale	10.0	15.4
– consolidation over 600mm	5.0	5.1
– consolidation under 600mm	23.0	20.7
– other (washout, soil as fill, etc.)	8.9	8.2
Subtotal	51.1	54.6
Substructure (hazardous ground)		
– clay (usually with tree problem)	10.0	17.8
– subsidence	3.4	4.8
– other (landslip, peat, made-up ground, etc.)	4.9	7.8
Subtotal	18.3	30.4
Substructure (miscellaneous)		
– problems caused by drains	1.7	1.7
– membranes and dpcs	1.3	0.6
– other (raft and retaining wall failures, sulphates, pile failures, etc.)	3.8	3.1
Subtotal	6.8	5.4
Superstructure		
– defective mortar	1.1	0.6
– lintels	3.8	0.8
– wet rot	2.5	0.5
– flat roofs	5.8	2.2
– pitched roofs	4.3	1.4
– joisted floors	1.6	1.4
– trussed rafters	1.0	0.5
– other (brickwork, chimneys, staircases, etc.)	4.5	1.7
Subtotal	24.6	9.1
Total	100.8	99.5

lems relating to the substructure in masonry construction. Coincidentally with the production of the standards and guidelines, the Joint Structural Division drafted a Code of Practice which dealt with masonry substructures and superstructures in single-storey residential buildings[10]. The Division accelerated its production of the Code to enable the NHBRC to draw on the material presented therein and to incorporate aspects of it in order to address specific issues.

In terms of the standards and guidelines, an individual classification of each site is required in accordance with the Code of Practice. A design-by-rule approach is provided in respect of class C, H, R and S sites for strip footings and slab-on-the-ground foundations. Compacted fills up to a height of 400mm are permitted in terms of the construction rules. The appointment of a competent person is required in respect of structures located on site classes other than C, H, R, and S and for aspects not covered by the rules. Competent persons are required to design and construct structures in accordance with the SAICE/IStructE Code of Practice.

The NHBRC requires a competent person (defined as a person who is suitably qualified and has the relevant expertise to perform the required duties and who has appropriate professional indemnity insurance, against which claims for negligent or incompetent work could be made) to certify the site class designation of a site. Mortgage lending institutions will not grant bonds without this certificate being produced. This has enabled the Code of Practice to be implemented on a systematic basis and has minimised the NHBRC's risk exposure in so far as foundations are concerned. This requirement has not, however, proved popular in some engineering circles as certain engineers and engineering geologists have been reluctant, or have refused, to assume responsibility for their site investigations.

The SAICE/IStructE Code of Practice design-by-rule approach to wall panels has also been incorporated into the standards and guidelines. The NHBRC procedures regarding the enrolment of houses and the construction controls are illustrated in Figs 1 and 2. These figures illustrate the controls which are in place and the potential involvement of structural engineers in the delivery of housing.

Current estimates are that approximately 28 000 units p.a. will be constructed under the auspices of the scheme at a selling price of approximately R2.8 billion[13]. The scheme is conservatively estimated in the near future to account for in excess of 40% of the total expenditure on top structures in South Africa. The scheme was launched in September 1995 for housing units having a selling price of under R65 000. This limit was, however, raised to R250 000 in February 1996.

Conclusions

The SAICE/IStructE Code of Practice enables individual sites to be classified in accordance with building practice. It classifies ranges of degrees of damage, based on ease of repair and degree of structural distress, in walls and floors, to which these elements may be subjected. This permits established engineering knowledge to be implemented on a systematic basis so as to ensure the satisfactory performance of masonry houses. It furthermore enables acceptable levels of expected damage to be defined and understood by all parties, permits houses having 90 and 110mm external wall thicknesses to be safely designed by means of a design-by-rule approach, and effectively removes the lack of harmony between wall panel sizes arrived at by following design rules and those obtained from rational design in accordance with the South African structural Codes of Practice.

The NHBRC's and financial institutions' requirement that individual events must be classified and certified by a competent person in accordance with the SAICE/IStructE Code of Practice ensures that ground movements are taken into account in the design and construction of housing. This procedure does not permit any misunderstandings to occur regarding the construction procedures to be adopted for a particular site as it ensures that the findings of those responsible for the site investigation are communicated to the house designer and the builder. It also requires those who undertake geotechnical investigations to account for their findings.

The NHBRC's standards and guidelines apply only to housing which requires mortgage finance. As a significant number of units will be built under the Government's subsidy scheme without mortgage finance, or by organisations, companies and utilities who do not require morgage finance, many sites will not benefit from the adoption of the systematic approach offered

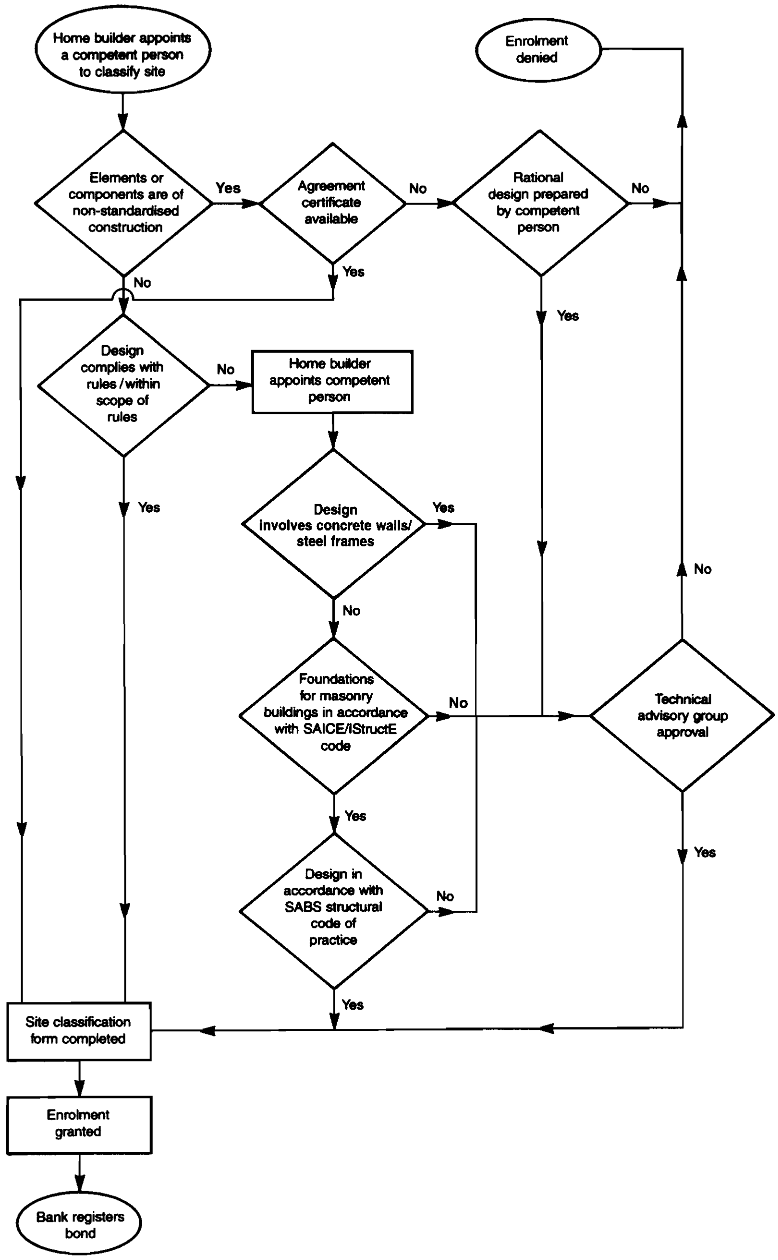

Fig 1. Procedures to obtain NHBRC enrolment and secure bond registration

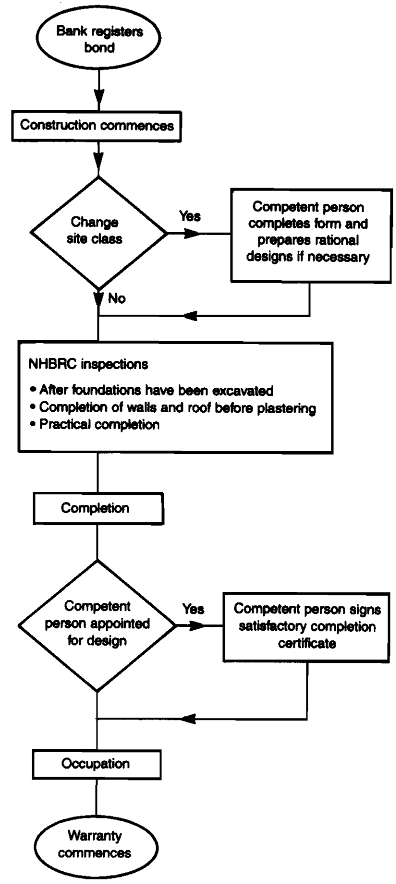

Fig 2. NHBRC construction controls

by the Code. Furthermore, such houses will be permitted to be constructed in accordance with the deemed-to-satisfy rules contained in SABS 0400 which are much less stringent than those required by the NHBRC. Accordingly, there is a need to harmonise the deemed-to-satisfy rules of the National Building Regulations with those contained in the NHBRC's standards and guidelines. In particular, there is an urgent need for the National Building Regulations to have deemed-to-satisfy construction requirements.

There is no substitute for doing things right. All the technologies and systems for the construction of quality houses are in place. All that now remains is for the rate of delivery of housing to increase sufficiently to meet the housing needs of the country and for the systems outlined in this feature to be implemented on all housing projects which involve masonry construction.

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