INTRODUCTION

Masonry wall failures are commonplace in South Africa, irrespective of the guidance given in the National Building Regulations and the Building Standards Act 1977 (Act No 103 of 1977) and various South African National Standards (SANS). Civil and structural engineers have continued to provide safe and economic structures over time, but it is evident that masonry façades, and in particular gable walls, are prone to structural failures and do not receive the attention of other common structural materials. These wall failures do not necessarily arise from natural causes. However, these inconsequential masonry envelopes, façades, cladding or walls seem to escape the attention of the structural engineer (competent person). Alternatively, these failures may be attributed to negligence, ignorance or mere oversight.

Such collapses attract press coverage only if there is a fatality, and thus generally go unnoticed.

This article reports on some recent masonry façade failures, with the intention of alerting structural engineers to the ever-present potential danger of structural masonry collapses, to provide an insight into the behaviour of masonry material façades, and to find a way of avoiding, minimising and offsetting these risks.

THE NATIONAL BUILDING REGULATIONS

The functional regulations contained in the National Building Regulations and Building Standards Act (NBR) for the maximum size of masonry wall panels with concomitant support conditions are provided in the deemed-to-satisfy requirements (empirical rules) of SANS 10400-K:2011: The South African National Standard, The Application of the National Building Regulations – Part K: Walls (previously SABS 0400:K-1990). SANS 10400-K is a comprehensive standard that inter alia outlines permissible wall panel sizes for single and double-storey dwellings and framed buildings, defines materials to be used, and details lateral support to walls, control and articulation joints and fixing details.

Irrespective of all the detailed information, the appointed competent person registered in the specific professional category of registration in terms of the councils for the professions identified in the Council for the Built Environment Act, 2000 (Act No 43 of 2000), fails to identify masonry members of a building falling outside the scope of the functional regulations as per their individual appointments in terms of SANS 10400-A:2010: The South African National Standard, The Application of the National Building Regulations – Part A: General principles and requirements. It appears that the appointment of the structural engineer in terms of Regulation A19 of SANS 10400-A has merely become a routine formality for local authority plan approval.

Intervention by local authority building control to identify these risk areas is probably limited in the absence of a thorough knowledge of the construction industry and standards.

Divided design responsibilities

In accordance with A19 of SANS 10400-A:2010, the appointment of an approved competent person lies with the owner of a building, who can retain one or more approved competent persons to take responsibility for a particular element in a building, and yet another competent person to assume responsibility for the building system or the overall stability of the complete structure during the design and construction stages. In many instances a number of engineers will be involved in designing various elements or sections of a structure, but never the entire entity. It is essential, therefore, that one identified engineer carries out this vital appraisal function, including consideration of any temporary measures which may be required during the construction stage.

Other factors

The writer is not aware of any graduate engineering course in South Africa in which structural masonry is a course offering. Perhaps the education, training and experience of some graduate engineers automatically preclude them from identifying and appraising masonry risk areas.

Since the architectural design intent historically involves masonry (walls), and as the principal agent entitles the architect to a fee inclusive of the value of the masonry, the client may be reluctant to pursue the structural engineer’s masonry input.

It is common for a sub-contractor to take on a “works package” for the masonry from the main contractor, with the...
emphasis on production, but with little knowledge of or interest in site practice and details.

NOTABLE RECENT MASONRY FAÇADE FAILURES

Industrial building – collapse of gable wall during construction
On 31 July 2015, at approximately 12:00, a gable wall collapsed during construction in Ophirton Township, Johannesburg, resulting in a fatality, as well as damage to the neighbouring building and stock. The 220 mm thick gable wall was 29 m long, 12 m high at the apex, with vertical control joints spaced at 4.6 m centres where supporting structural steel columns were located, as shown in Photo 1. There is no record such as a wind storm on the specific day. Approved building plans could not be sourced from the local authority.

- The entire gable wall was free-standing and not anchored onto the supporting steel structure.
- Dissimilar masonry units (concrete and fired clay) were built into the same wall panel, which is not permitted if wall ends are in contact with each other (SANS 2001 standardised construction specification series, i.e. Clause 4.3.7 of SANS 2001-CM1:2007; The South African National Standard, Construction works. Part CM1: Masonry walling).
- The multi-leaf wall was not cross-bonded mechanically or otherwise (Clause 3.24.2 of SANS 2001-CM1:2007).
- The Department of Labour (DoL) issued a prohibition notice in terms of the Occupational Health and Safety Act, Act No 85 of 1993 on 5 August 2015 and revoked it on 14 December 2015. The DoL to date is silent on the outcome of its investigation.

Due to the scant regard to recognised good building practice, the writer can only surmise that the gable wall was built illegally by unskilled labour without qualified supervision.

Golf club hall – collapse of gable wall
On 3 April 2015 one gable wall of the hall collapsed, causing damage to the 300 m² roof. There were no injuries. Photo 2 shows the collapsed masonry gable wall. The weather record for the specific day did not show any wind speed above the norm. The gable wall was 14 m long, 6.5 m high to the apex and was supported at the ends only by return walls. The side walls supporting the roof trusses were 20 m long and were also supported by the end return walls, while the gable wall on the other side of the building had internal partition walls providing lateral support.

- The gable wall geometry falls outside the scope of the set of deemed-to-satisfy rules of SANS 10400-K, i.e. the gable wall is too slender. In such cases a competent person registered with the Engineering Council of South Africa (ECSA) in terms of the Engineering Profession Act (Act 46 of 2000) shall design and inspect the wall.
- It can only be assumed that no one identified that the gable wall required a rational design and was therefore built illegally.
- The multi-leaf wall was not cross-bonded (Clause 3.24.2 of SANS 2001-CM1:2007) mechanically or otherwise.

Industrial building – partial failure of gable wall
During a wind storm in July 2005 the gable wall, with roller shutter doors, of a
factory in Kaya Sands was blown inward. Photo 3 shows the leaning gable wall. A structural steel superstructure was clad with masonry and IBR-profiled metal sheeting. The gable wall comprised a 230 mm face brick wall, 30 m long with a return wall in the centre; the wall was approximately 9 m high at the apex. A competent person designed and issued a certificate of completion for the structural steel superstructure, but the unstable masonry gable wall had gone unnoticed.

The geometry of the gable wall falls outside the scope of the set of deemed-to-satisfy rules in SANS 10400-K and the wall was further weakened by the penetrations.

Academic building – gradual structural deterioration of masonry envelope

To accommodate a cubistic architectural theme for an academic department at a local university, deeply recessed windows were used by the architect, necessitating cavity walls comprising 115 mm thick masonry leaves with a 345 mm cavity. The masonry envelope was supported by a reinforced concrete frame, with the cavity wall panels 6 x 3.7 m in extent. Photo 4 shows a part elevation of the warped and cracked wall panels.

It is evident that the structural responsibility of the structural engineer was limited to the reinforced concrete frame, with the masonry façade merely drawn as parallel lines on the architectural drawings. Most, if not all, of the wall panels cracked and dislodged laterally from the supporting structure. Sections of wall were exposed, revealing a cavity wall devoid of wall ties. Wall panels were anchored to the reinforced concrete frame with randomly spaced slender hoop iron with a sweeping long bend between the mechanical anchors affixed to the concrete column. The cavity walls were not provided with weep (drainage) holes and no provision was made to direct moisture outward using a damp-proof course.

The geometry of the single-leaf wall panels falls outside the scope of SANS 10400-K.

SANS 10164, Part 1 of the South African Standard for The structural use of masonry, Part 1: Unreinforced masonry walling gives guidance for lateral support to masonry panels. Metal anchors shall be rigid and calculated, but should be evenly distributed at centres not in excess of 300 mm.

SANS 10164, Part 1 limits the size of a cavity to 150 mm. Cross-bonding the
masonry leaves with internal wallets is required to form a diaphragm wall.

- SANS 2001-CM1 provides damp-proof course details to prevent rising damp in walls and to direct moisture outward from cavity walls.
- Cavities were filled with debris. If the need for a suitably competent person had been identified at the outset, the fee to formalise the design intent to facilitate a fit-for-purpose masonry envelope would have been minimal compared to the subsequent cost of the remedial work.

**Commercial building in KwaZulu-Natal – collapse of façade during a storm**

On 14 December 2008 a high wind caused two cavity wall panels to fail at a shopping centre in KwaZulu-Natal. The one panel, some 6 x 6 m in extent, at first floor level over an entrance, collapsed while the outer leaf of the other panel leaned against the inner leaf. The cavity in the wall was 150 mm and, as shown in Photo 5, was tied with masonry reinforcement (brick force) and binding wire as opposed to using wall ties.

- Wall ties shall be subject to a rational design taking into account the wind pressure for the specific terrain category.
- It is evident that construction supervision was lacking.
Masonry envelopes for mass-produced standard-sized prefabricated structural steel buildings (farm buildings)

Cost-effective, flimsy, unclad structural steel buildings often end up being enclosed with a masonry envelope. Side walls (without penetrations) remain functional as a cracked section if adequately supported between columns of the superstructure (normally a portal frame). However, gable walls often fail in the absence of a supporting column since the wall geometry falls outside the scope of SANS 10400-K. The design intent of these farm buildings does not necessarily cater for masonry cladding.

Often the gable wall is toothed in at the return wall on the leeward side, resulting in a spectacular zip failure as the gable wall collapses away from the building.

Clause 4.4.5 of SANS 2001-CM1 does not permit toothing-in as a means of joining intersecting walls.

Commercial building in Sandton – random collapse of façade

The partial collapse of the masonry façade of the building located in Sandton occurred in the latter half of 2016. Photo 6 refers. The parapet wall was approximately 38 m in extent and projected past the roof line by 4 m. The stability of this wall probably would not have escaped the professional team's attention if located at ground level, since a 230 mm freestanding boundary shall not exceed 1 800 mm in height, as directed in Table 17 in SANS 10400-K. According to a reliable source the contractor was requested to make good the collapsed wall at his own expense; the façade was however replaced with a light-weight ductile cladding system following the roof contour.

The use of masonry as a structural medium will be optimised once the behaviour of this brittle unreinforced masonry material is grasped.

Photo 6 Façade consisting of a freestanding wall at height

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Photo 7 Façade with pier supports

Mall on East Rand – collapse of façade

Late on Saturday, 2 February 2008, emergency personnel were still searching for survivors after a section of a masonry façade of a shopping complex near Brakpan on the East Rand collapsed into a parking area, killing three people as their car was crushed by the falling wall. The façade collapsed during extreme weather conditions. A paramedic said: “The car was crushed to the extent ... that it was almost at knee-level. They [rescue workers] couldn’t even tell what car it was.” A six-month-old baby and a 13-year-old boy were seriously injured.

Photo 7 shows a part rear view of a remaining freestanding façade with the parapet wall extending past it. The freestanding wall at roof level comprised a 230 mm thick masonry wall 2 900 mm in height, with 575 x 230 mm piers projecting past the face of the wall at 5 000 mm centres; there are no piers at the ends of the wall. The façade was between 8 to 12 m above ground level. Not evident from this photo is that the pier was toothed in at every tenth course with a considerable gap between the wall and the pier. Problems of lack of bond between pier and wall for neighbouring façades were apparently noted earlier and steel brackets were added.

- The multi-leaf freestanding wall, as well as the neighbouring parapet wall, were not cross-bonded, therefore structurally compromising the wall.
- Interestingly, the freestanding wall collapsed along a near-horizontal line along a bed joint ten courses above the roof level and not along the lowest bed joint.
- Irrespective of the published guidance given in SANS 10400-K and SANS 2001-CM1 on control joints, the walls were built in one continuous length.

CONCLUSION

Masonry façades built in accordance with SANS 2001-CM1 and compliant with the NBR are expected to be fit for purpose and serviceable over the life cycle of the building. It is evident that the contractor is responsible for a failed façade complying with the empirical rules in SANS 10400:K built to SANS 2001-CM1 in the absence of input of a competent person.

When larger façades (subject to a rational design) fail, resulting in pecuniary loss, injuries and fatalities, the appointed competent person in terms of SANS 10400-A is let off the hook by virtue of a fragmented appointment limiting responsibilities to a specific member or structure. According to SANS 10400-A, the owner is responsible for appointing approved competent persons for satisfying the functional regulations to a particular structural system, and the owner is also responsible for appointing an approved competent person to assume responsibility for the design of such a system in its entirety (where parts of the system are to be undertaken by other competent persons).

The Construction Regulations 2014 of the Occupational Health and Safety Act, 1993 (OHS Act) require the owner of a structure to ensure that inspections of that structure are carried out periodically by competent persons in order to ensure that the structure is safe for continued use.

The OHS Act requires the designer of a structure to inform the client in writing of any known or anticipated dangers or hazards relating to the construction work. But let us not beate the bush – if we as competent persons fail (due to ignorance, negligence or insufficient knowledge) to identify a masonry façade of which the collapse is inevitable, how can we expect the credulous client or owner to do so? This does not bode well for us as structural engineers subscribing to the Code of Conduct for Registered Persons. The construction industry has become cut-throat and competitive, is devoid of skilled personnel and is subject to questionable procurement procedures. But our vigilance and the most basic knowledge of our most common building materials WILL save lives.

The Joint Structural Division (JSD) of SAICE and IStructE has published articles and guidelines in an attempt to make the construction industry safer. The JSD Guide to Good Practice and Checklist Guides come to mind, and a non-statutory voluntary listing of professionals with defined standards of competence in specialist areas has been mooted.

Over time the NBR, OHS Act and other appropriate bills need to be amended to cater for this glaring deficiency in the construction industry. In the interim, a concerted effort can be made at plan-approval stage to ensure that non-compliant masonry façades are identified either by the architect or the building control officer. Alternatively, should the appointment of a competent person not be made compulsory for all masonry construction, however mundane?

REFERENCES

Engineering Profession Act (Act No 46 of 2000).