USING TILES FOR EXTERNAL CLADDING

Introduction

External tiling has been a traditional method for finishing buildings in Hong Kong for many years. It is often favoured by property developers because it is perceived to be a comparatively low cost, low maintenance solution for medium-high rise buildings where access for repair and maintenance is expensive. 20 years ago mosaic tiles were cheaply available from China and traditional skills were also easily available. There are several examples of old buildings in Hong Kong which have survived with the original mosaic clad finish without any failure or debonding. So we know that this method can be successful when carried out properly.

However, over the last 20 years or so there are have been many tiling failures in Hong Kong. This has largely resulted from a change to the use of discrete tiling systems without upgrading the materials and workmanship to match the changing situations. This article examines some of the reasons why tiling fails and demonstrates why the risk of failure can be high. It also suggests ways that the situation can be improved.

Diagram 1 illustrates the design and workmanship factors involved in executing a tiling system.

**Diagram 1: Design and Workmanship factors in a tiling system.**
**Design and Specification**

- Although quite sophisticated specification methodologies have been developed for curtain walling and cladding the same cannot be said for tiling systems. For the main part specifications are fairly primitive and no international approaches are generally available. Some standards and codes of practice exist in Europe the America’s and Japan and there are national standards for tile quality available. Heavy reliance is placed on the supposed specialist expertise of the applicator to get things right. The situation is compounded by the existence of a wide range of commercial products and the existence of different traditional practices around the world (eg. the ‘partial spatterdash’ bonding method in HK). These factors together with the wide range of environmental conditions, architectural styles and structural backgrounds make it difficult to arrive at a comprehensive code of practice or design methodology which is both sufficiently useful and authoritative.

- Diagram 1 shows that the main issues for tiling system are firstly in ensuring that adequate adhesion is obtained between the various contract surface and secondly in providing stress relief for the various stresses that can develop in the tiling. The current Hong Kong practice is to specify the materials required (either in generic or proprietary terms) and to show the location of movement joints in the tiling system. Diagram 1 however, shows that there are a minimum of 3 contact surfaces to be considered and that there can be as many as 6 or 7 depending the use of bonding agents and numbers of render layers employed. This increases the risk of failure considerably.

- To a greater or lesser degree the material properties of the render system are determined in-situ as work proceeds and they are difficult to check in-situ by non-destructive means. Current Hong Kong practice relies on the tiling workmanship to achieve the material properties by following the manufacturers recommendations or the specification requirements. As these remain largely unchecked the reliability of the tiling is quite low.

**Workmanship**

- Diagram 1 lists 30 points which are controlled by workmanship and which have a direct bearing on the quality and performance of the tiling system. In the current Hong Kong approach these items are usually not subject to independent checking or to any quality system. The success of tiling systems are highly dependent on workmanship which is not checked adequately, therefore there is a high risk of failure with these systems.

- The following common workmanship problems have been associated with the failure of tiling systems:
  - Poor concrete alignment leading to large build-up in render thickness.
  - Inadequate surface preparation of concrete or use of bonding agents causing low bond strength.
  - Poor compaction and bonding of render layers.
  - Render compositions with too much cement causing shrinkage.
  - Inadequate position and fixing of render causing debonding.
  - Poor preparation of render surface or application of bonding agent leading to adhesion failures.
  - Poor tile bedding technique or application of tile adhesive leading to adhesive failure.
  - Joints not formed through to the concrete surface leading to compressive adhesion failures of the tiling system.
• The workmanship requirements can differ widely for different proprietary materials or tiling systems. Adequate time needs to be provided at the beginning of contracts to allow the tiling contractors to develop appropriate techniques, method statements and monitoring systems. It is not possible to embody all the appropriate workmanship procedures into a general specification. The design and specification system need to be developed together with the tiling contractor into appropriate method statements which can be checked.

Sources of Stress in Tiling
Probable causes of excessive stresses in the tiling system are as follows:

• Wind Drag Forces
Loadings acting on external wall tile are independent of the building height except wind loads which gradually increase with the height. Wall tiles at high level are usually subject to a large wind drag force, however, the magnitude of wind pressure is very small in comparison with the minimum design strength of the tile adhesive.

• Thermal and radiation effect
External wall surface is subject to radiation under strong sunlight. High surface temperatures in the external wall tiling induce large thermal stresses in the tiling system. The thermal stresses due to temperature change for thick wall tiling may cause bowing and debonding of wall tiling which is formed with various non-homogenous materials in layers.

• Building Movement
Foundation settlement is permanent building movement and lateral building movement due to wind loads is temporary movement. Tall buildings often have a massive and deep foundation and so building settlement is closely related to soil properties and the foundation type rather than the building height. Large building movement may cause background movement for the external wall tiling and this may result in a higher probability of tiling failure or surface cracking.

• Elastic Deformation of Vertical Building Elements
Deformation of building elements such as columns and walls occur when they are stressed under loading from the superstructure. Contraction of concrete structures can induce peel stresses in the contact interface. There is no risk of tiling failure when the peel stress does not exceed the adhesion strength of the render materials. However, there is a high potential of tile/render debonding if the peel stress increases up to the adhesion strength of the tiling.

• Building Oscillation
Tall buildings have a long natural period of vibration. Frequent reversal of loads can reduce the adhesion strength of the tiling system. If the resultant stress is less than about half of the adhesion strength, the phenomenon of material fatigue may become significant.

• Shrinkage
Concrete exhibits progressive shrinkage over a long period of time during hydration. If reduction in length due to shrinkage cannot take place as contraction of the render material in the contact interface is constricted, peel and shear stresses will be induced in such condition.

• Long Term Creep
Creep is the slow deformation, additional to elastic contraction exhibited by materials under sustained stresses and it proceeds at a decreasing rate with time. Shortening of concrete structures can induce stresses in the contact interface under the effect of long-term creep.
**Engineering Considerations in the Design of External Tiling Systems**

The durability of rendering and external wall tiling is influenced by factors such as adhesion strength of the materials, control of the surface cracking and crazing, build-up of internal stresses, moisture movement, atmospheric pollution, the condition of the background and the method of application. Materials having a high bond strength should be selected to form a reliable tiling system. The actual adhesion strength for a proposed tiling system should be determined with a number of pull-off test results to substantiate that the specified strength and quality of workmanship can be achieved under site condition.

Some induced stresses can potentially cause debonding and failure of external tiling. If such control stresses are minimised and have been taken into consideration in the design stage, the risk of tiling failure can be greatly reduced.

Thermal stress and induced stresses from long term shrinkage and creep are substantial control factors likely to cause excessive peeling stress. The peel stress due to the thermal effect of external tiling under strong sunlight may be greater than the minimum adhesive strength or render strength. The thermal effect on the wall tiling can be reduced if thin layers of rendering and rendering materials with a low elastic modulus are used. In addition more movement joints in the wall tiling can release build-up of induced peel stress due to thermal effect.

Early age shrinkage may cause significant contraction of materials particularly when inadequate curing occurs on site. Fine cracks may form on the render surface or concrete substrate at an early age before installation of wall tiles. Wall tiles glued on finely cracked surfaces may have inadequate bond strength. Long term shrinkage on concrete structures may also lead to significant background movement particularly when the drying process of a new massive concrete structure is not complete at the time of commencement of the tiling work. Stresses are induced in the contact interface of the tiling and concrete structure due to the contraction of the background and so some loss of adhesion and cracking may be caused.

The sustained stress and the age of the structure at which loading starts can have a large influence on the creep value. When the external tiling work for tall buildings commences prior to the completion of superstructure construction, creep and loading strains due to the building and imposed loads in the construction stage can result in a relatively large background movement for the wall tiling. Such contraction is greater in tall buildings and can induce large peel stresses in the wall tiling. In order to minimise the risk of tiling failure, surface rendering and wall tiling works should be scheduled as late as possible in the construction programme. This allows sufficient interval for most of initial creep and mechanical strain to have taken place before installation of wall tiles. Moreover the magnitude of the creep is smaller for more mature concrete.

**Reducing Risk in Tiling Systems**

There are several ways of reducing risk and there an improvements that can be introduced to provide a more sophisticated approach for Hong Kong. There are considerable implications to be accepted in terms of design approach, workmanship standards, conditions of working and accessibility, quality control systems, and contractual procurement. Such improvement will mean higher costs.

- Design and Specification

  There is a very close relationship between design and tiling system selection. Outline designs must provide performance requirements, design and workmanship limitations, standards to be achieved, and requirements for QA/QC control systems. The contractor must develop specific tiling systems, method of working and control systems to demonstrate compliance both in terms of design and workmanship.
• Materials
Many failure are caused by unacceptable variations in materials or materials performance. All materials should be delivered to site as proprietary pre-packaged products to minimise workmanship errors in material preparation. All materials should be tested and subject to routine checks during the construction.

• Concrete Finishing Standards and Tolerances
The standard of structural concrete finish and alignment required for tiling must be improved in order to increase the overall chances of tiling success. Concrete finishing must be inspected, approved or repaired as concrete work proceeds and not left to the end of construction. Corrective action should be taken immediately. Concrete hacking and repair as a general procedure is not acceptable for tiled finishes. Any minor repairs need to be conducted and approved as part of the structural process and not included in the tiling process.

• Access
Fully boarded safety access to all levels of tiling needs to be provided for tiling work and inspection procedures. This is a multistage process requiring inspection at many stages.

• Tile System Design and Layout
Variations in tile system thickness needs to be controlled as work proceeds and an appropriate predetermined system used for each variation. Measurements need to be made of structural variations in order to determine tile finish alignment and tile system thickness. This process and instruction should be controlled by an architectural technician on site.

• Control/Check Points
Control points need to be established at each stage in the tiling process for QC checking together with testing or verification of standards, and then built into an overall QA system.

• QA System
A quality assurance scheme should be operated by the tiling contractor and agreed with the architect. Third party independent checking of the QA and QC work should conducted at an agreed level of inspection as work proceeds.

• Workforce
Tiling work is a specialist skilled activity and should not be carried out by main contractors using general labour. Specialist tiling contractors should provide a fully trained workforce together with adequate numbers of experienced supervisors and foreman. Training should lead to a registered tiling workers scheme for any particular project and tiling system. Access should be provided by the main contractor for training before workers can be certified to proceed onto the project. No subcontracting of tiling work should be permitted by specialist tiling contractors.

Conclusion
The design and construction of tiling systems in Hong Kong is not taken seriously enough and the continued use of low-skilled traditional approaches to tiling is not compatible with modern construction. Radical changes are needed in this industry if costly failures are to be avoided.