CONTENT

1.0 INTRODUCTION

1.1 Building Description

The building is located at 115 Airport Cargo Road. This is a conventional 8-storey industrial warehouse building cum office building, known as Cargo Agent Building 'C'. The building is built in 1987 and managed by the Civil Aviation Authority of Singapore (CAAS).

The building's occupancies are as follows:

1st and 2nd Storeys	-	Warehouses; Mezzanine Offices (offices within the warehouse); and Carpark
3rd to 8th Storeys	-	Offices

2.0 CAUSES OF DEFECTS

2.1 Background

The wall and floor finishes of the main lobby are made up of polished homogenous ceramic tiles with expansion joints. Over the years, majority of the ceramic floor tiles were either damaged or worn out and there have been numerous incidents of "Arching and Lifting" of the floor tiles. After few rounds of replacement to the damaged floor tiles at the main lobby from different batches of ceramic tiles supplied by different suppliers have resulted in colour variation and this in turn caused inconsistency and patchy floor finishes which affect the aesthetic of the whole lobby, thus giving an impression that the building is poorly maintained.

Photo 1 - Arching and lifting of floor tiles

Photo 2 - Another view of the defect

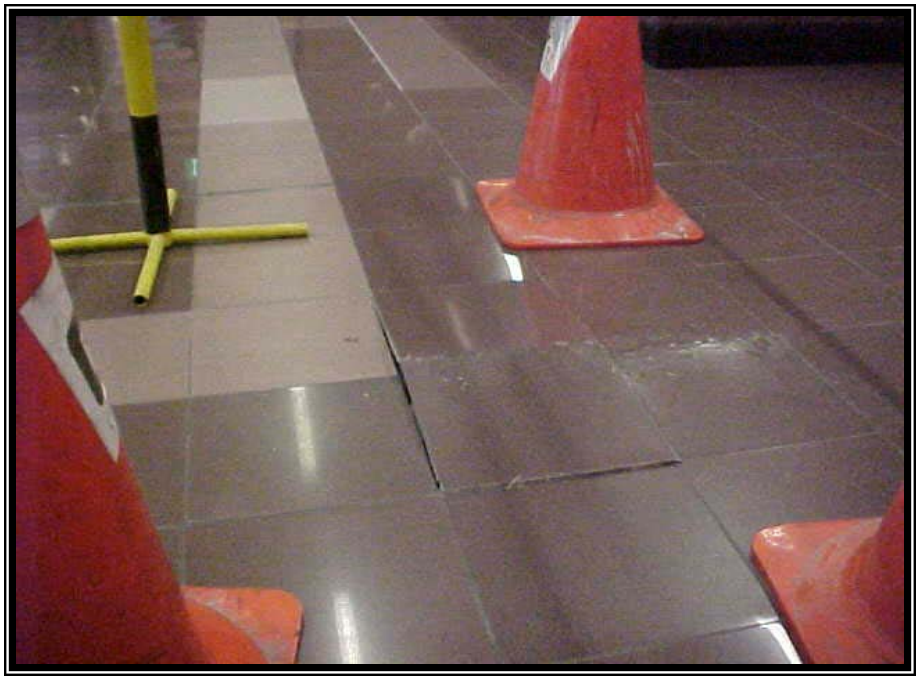


Photo 3 - Variation of colour after a few rounds of replacement

Photo 4 - Inconsistency and patchy appearance

After carrying out a comprehensive site survey and investigation, the possible causes of arching and lifting of the floor tiles are identified and grouped into three main categories namely the Expansion Joints, Base Concrete/Screed and Vibration.

2.2 Expansion Joint

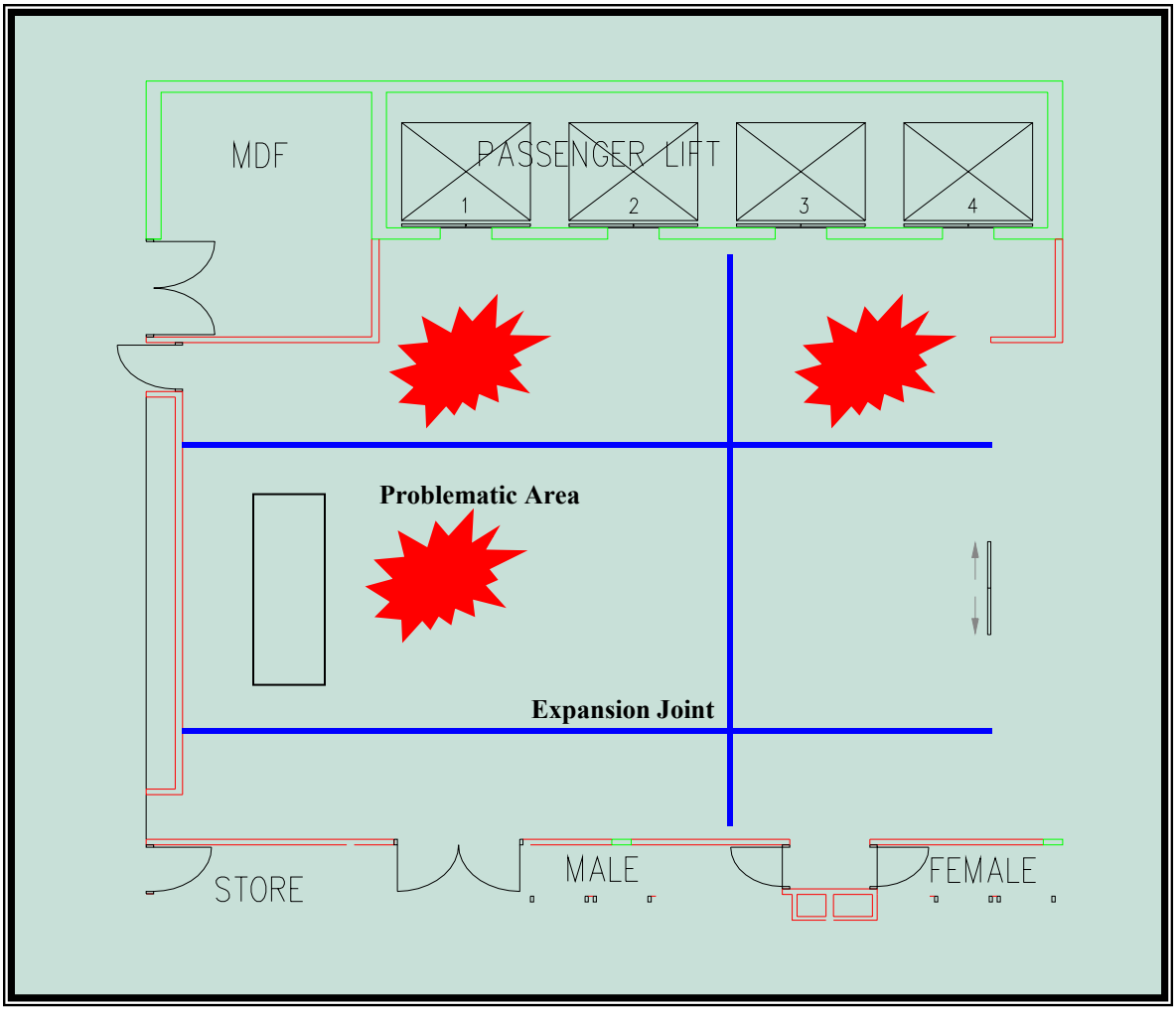
The current expansion joints or movement joints might be inadequate or under-design to cater to the various differential movements such as structural movement, movement between the tiles & substrate and the expansion & contraction of the cement mortar tile bed. These joints might also be defective or worn-off due to the expansion joint reaching its life-span.

Photo 5 - Existing expansion joints provided on site

2.2.1 Provision, Layout and location of Expansion Joint

The provision of expansion joints at the correct locations is crucial for the expansion joints to serve its purpose. Figure 1 illustrates the existing layout and location of the expansion joints and the past locations of arching and lifting tiles.

Figure 1 - Layout and location of expansion joints and areas of arching and lifting



As a guide, the following are some of the recommendations in the provision, layout and location of the expansion joints:

- Provide movement joints over movement joints in the background substrate.
- At junctions between different background materials.
- At fixtures interrupting the tile surface, e.g. columns etc.
- At internal vertical corners.
- At perimeter of floor.

- At maximum 5 metre intervals in a grid pattern.
- Joints shall go right through the tile and adhesive bed to the background and be kept free from dirt and adhesive droppings.
- Joints shall be not less than 4mm and not greater than 10mm wide.
- Seal all movement joints with flexible sealant.

2.2.2 Condition of Expansion Joint

The conditions of the joints are important since damaged expansion joints would fail to serve its purpose. Determining the lifespan of the expansion joint is also crucial in ensuring that the expansion joints are in good working condition.

2.3 Base Concrete/Screed

The differential movement between the ceramic tiles and base concrete/screed would contribute significantly to the arching and lifting of the tiles. The differential movements are mainly due to the physical properties of the tiles and base concrete/screed in reacting to expansion and contraction and they include:

- The drying shrinkage properties of the screed.
- The different co-efficient of thermal expansion of the tiles and base concrete/screed.
- The absorption characteristics of the tiles and base concrete/screed.

All these characteristics would ultimately lead to the build-up of stresses which in turn result in the arching and lifting of the tiles.

Figure 2 - Drying shrinkage of screed

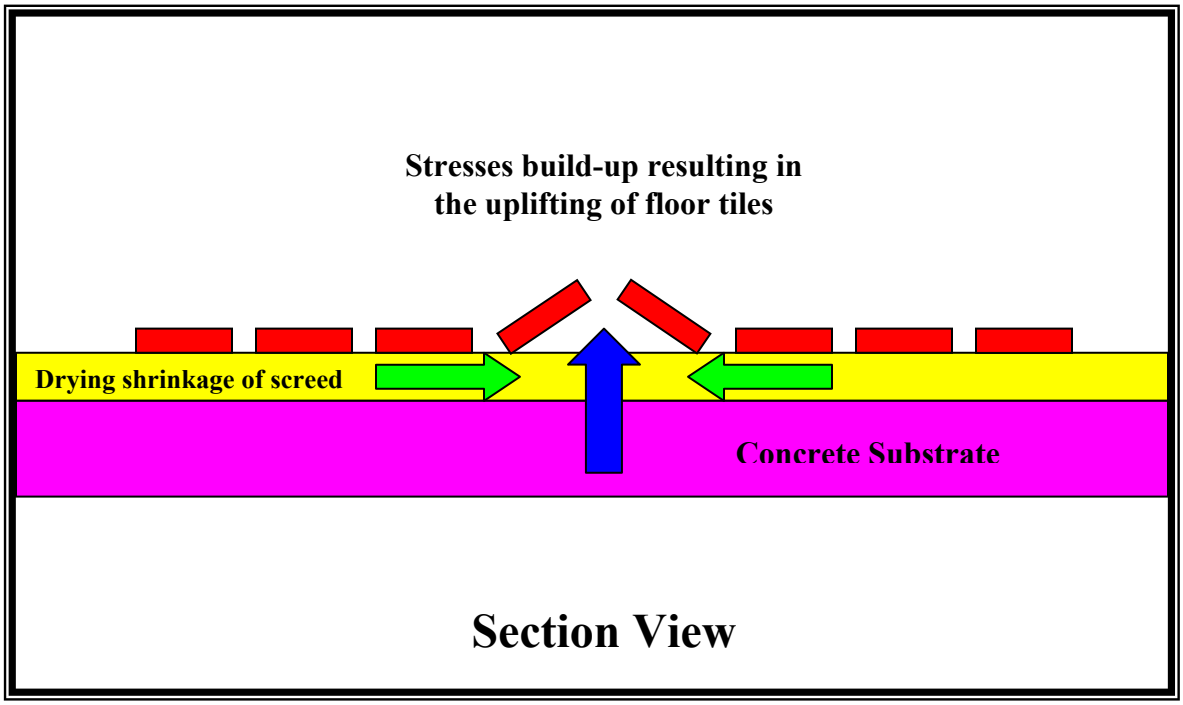


Figure3 - Thermal expansion of different materials

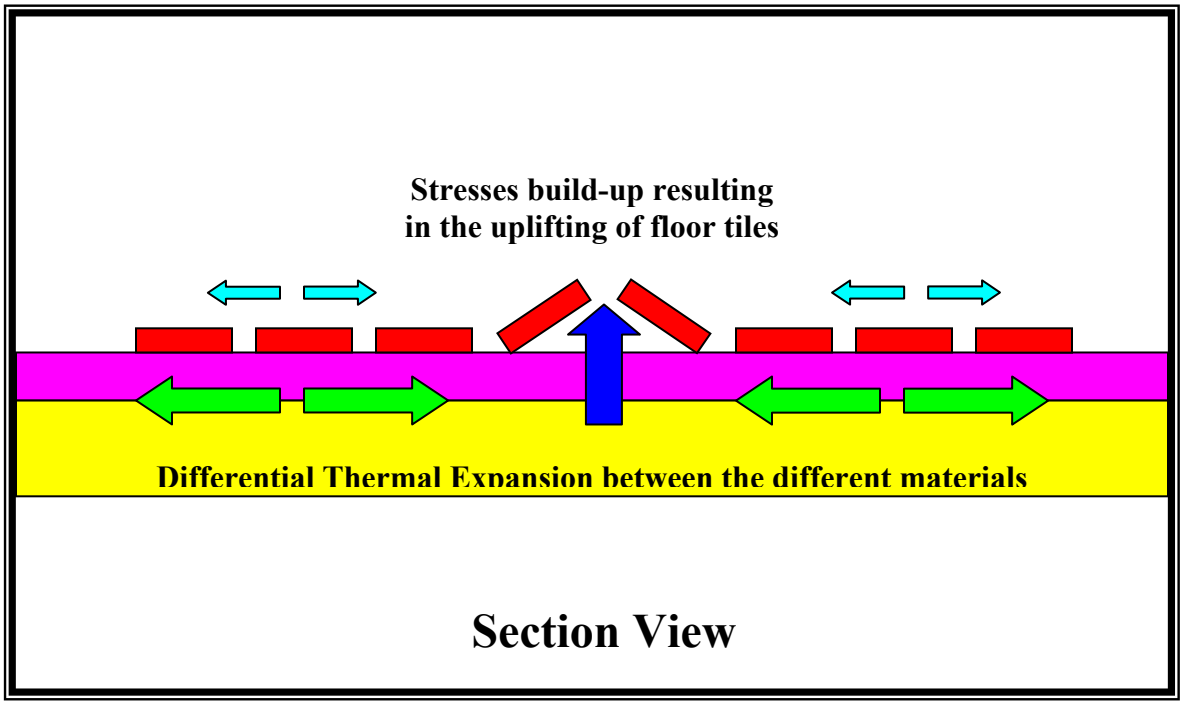
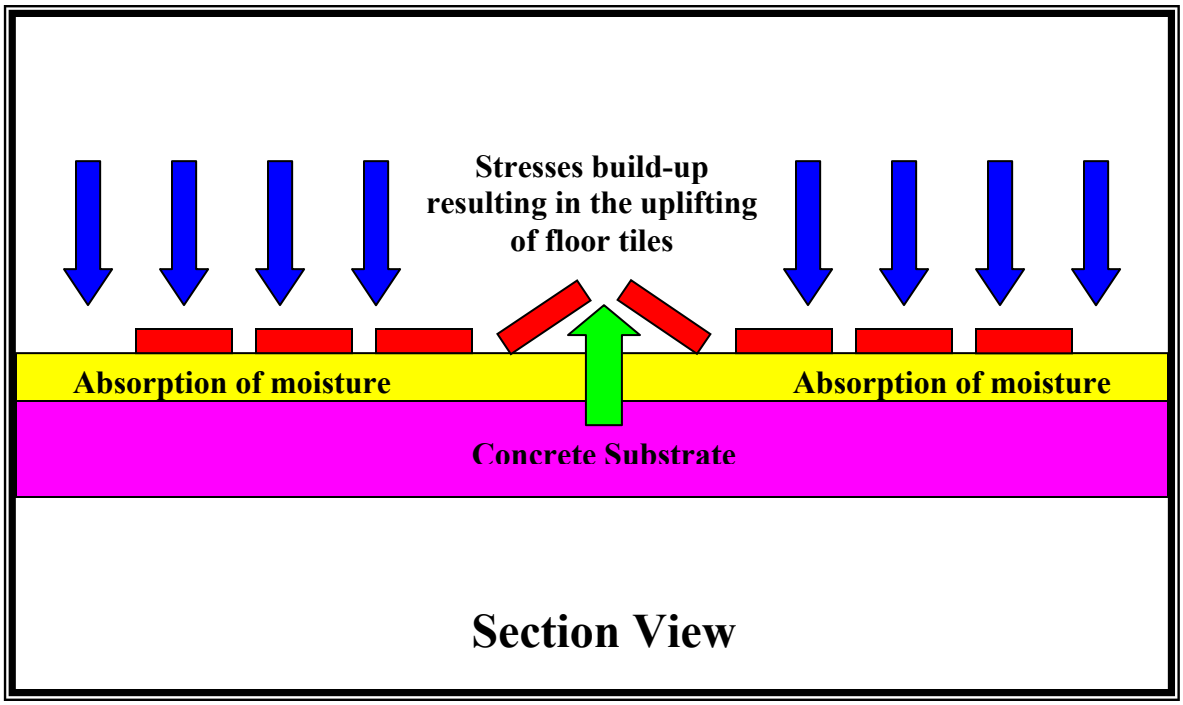


Figure 4 - Absorption characteristics of materials



2.4 Vibration

The 1st and 2nd storeys are used as warehouses and thus heavy equipments and vehicles often operate on these 2 levels. The main lobby is located underneath the ramp that serves between these two levels, the impact and vibration generated by the heavy trucks, lorries and forklifts might have caused differentiate structural movement and building settlement that might in turn cause the arching and uplifting of the floor tiles at the main lobby.

Photo 6 - Up-ramp located above the main lobby

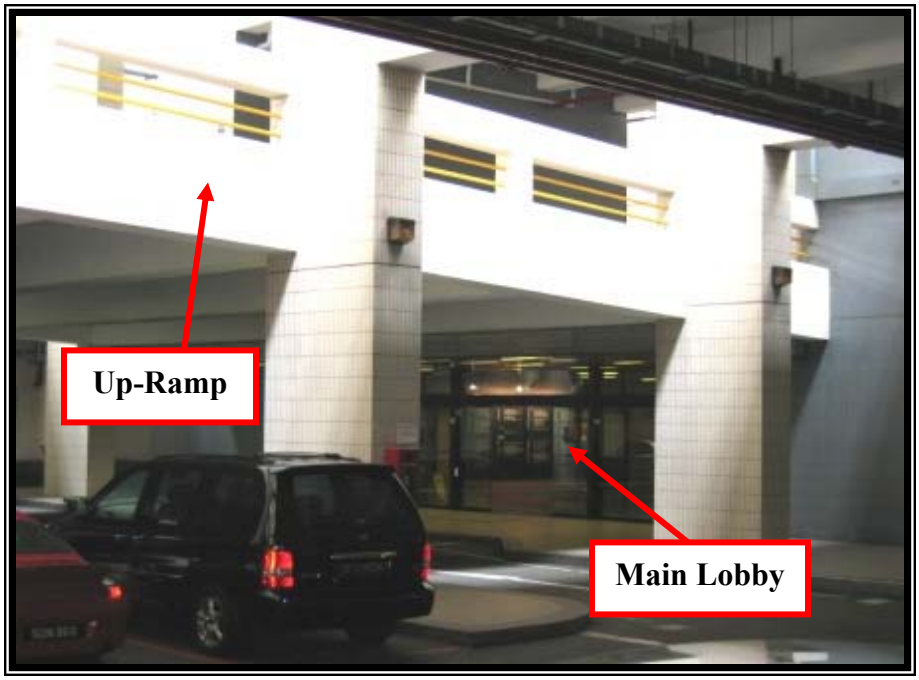


Figure 5 - Plan View of up-ramp and main lobby

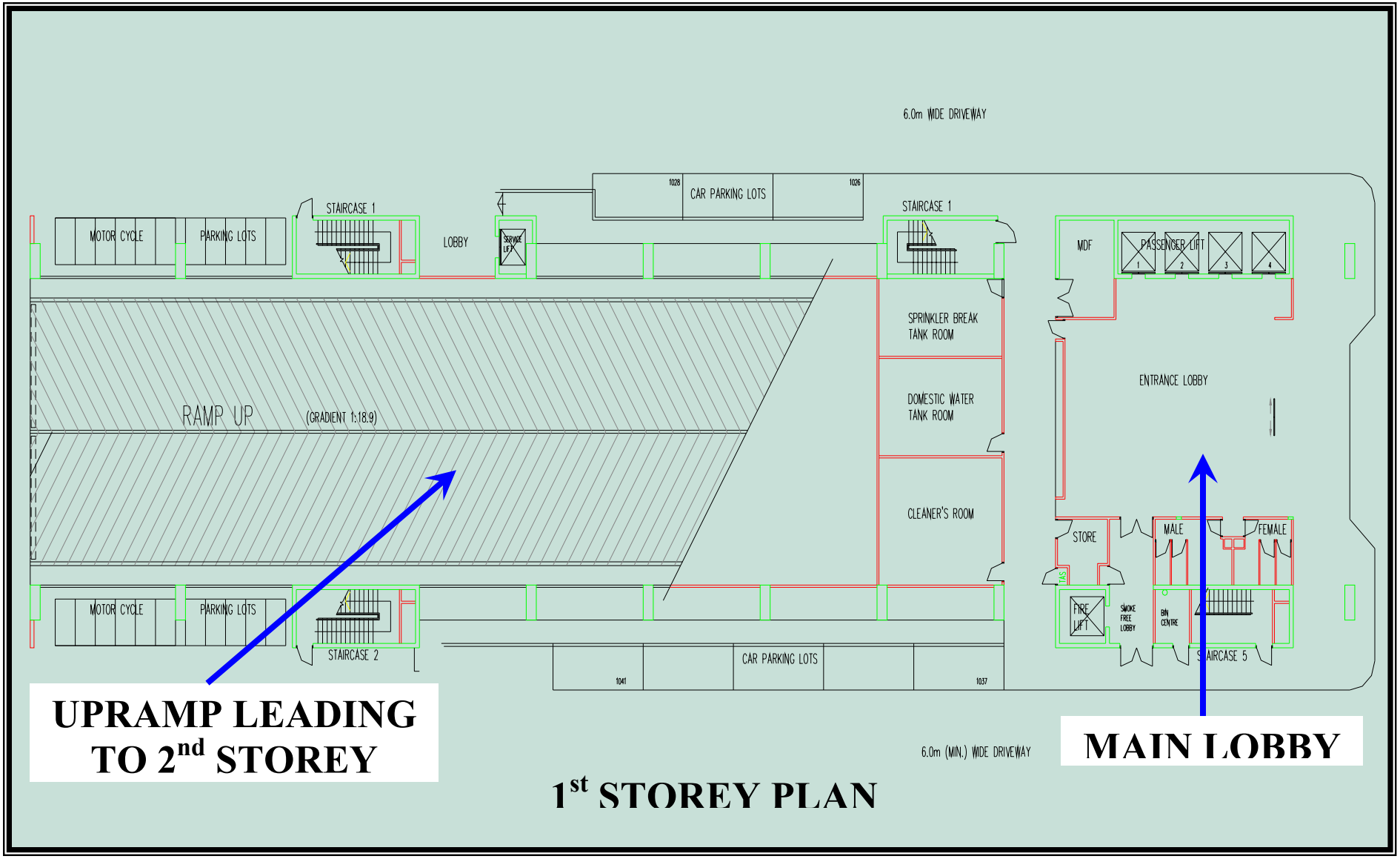
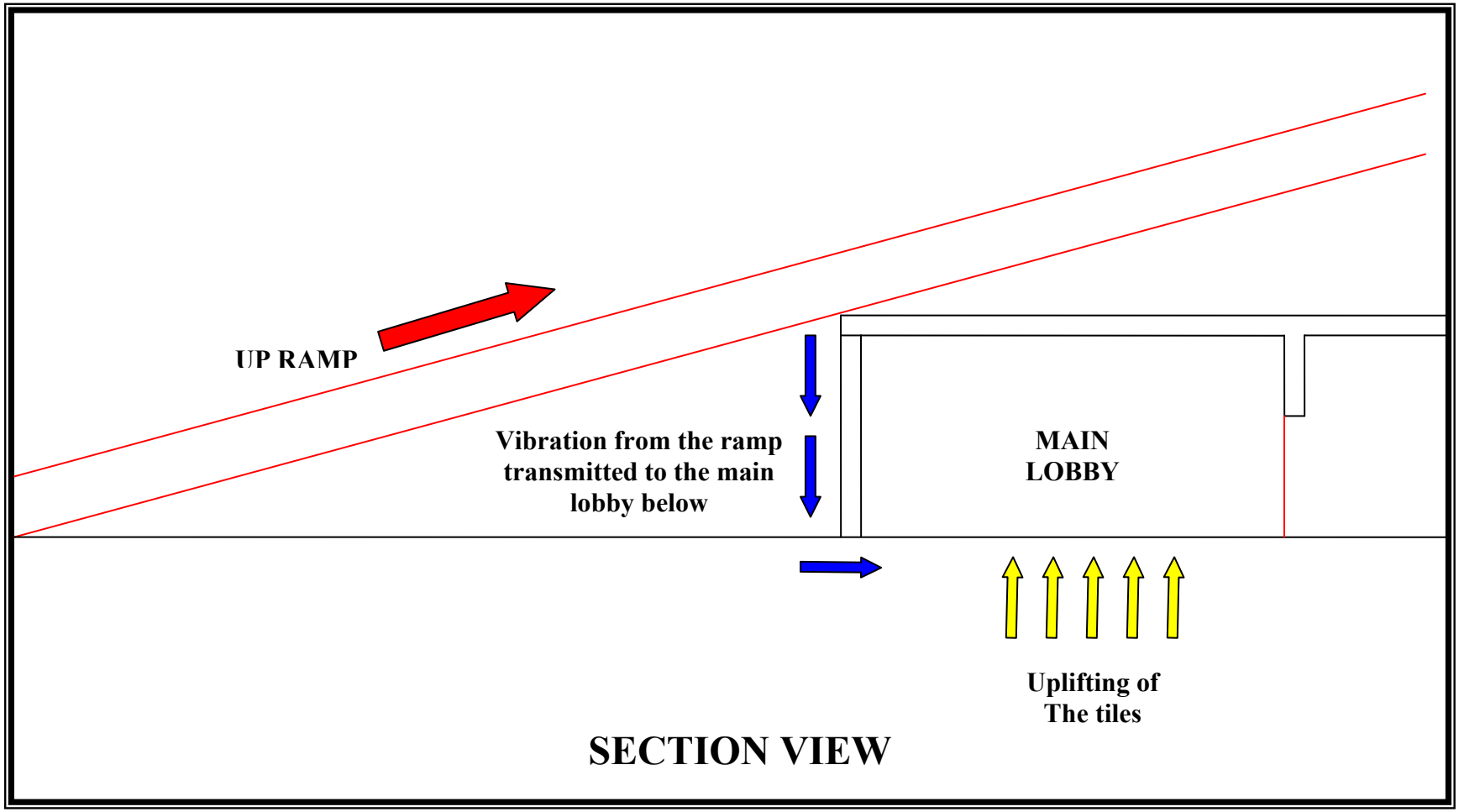


Figure 6 - Section view of up-ramp and main lobby



3.0 GOOD PRACTICES

Some of the most common mistakes when laying ceramic floor tiles include:

- Poor alignment of the ceramic tiles
- Not wiping off the excess ceramic tiles grout before it hardens
- Not laying ceramic tile flooring on a level or smooth floor
- Not allowing concrete to fully cure before installing the ceramic tiles

To ensure good adhesion between the tiles and substrate, some of the good practices should be adhere to and these will be cover in the following sections.

3.1 Surface Preparation

The concrete substrate should be dry, clean and flat. Any holes or irregularities should be filled with a suitable levelling compound 24 hours before laying the tiles. If the floor is uneven or with unsatisfactory gradient, it can be re-laid , after forming keys, with a 2 to 1 fine sand and cement mixture with additive. This should only be done in cases where the surface is quite unsatisfactory since the work process is tedious. For new concrete, allowance should be made for at least 28 days for the concrete to cure. This method prevents loose and cracked ceramic tiles.

3.2 Laying the Floor Tiles

Spread about $1m^2$ of adhesive at a time with a notched trowel. Use a notched trowel which will obtain complete adhesive coverage. Firmly push the tiles into the adhesive, spacing each one with a tile spacer to allow the space that look best (these are removed before grouting). Spread out enough of the bonding agent, approximately enough for 2 to

3 tiles, before it sets. When laying ceramic tile never slide of drop into place the ceramic tile. The proper method for laying ceramic tile is to gently twist them into place and to work one small section or row at a time. It is vital to pull up a tile every so often to ensure complete coverage of adhesive on the tile and floor. Ensure to wipe off any excess adhesive throughout the whole laying process and most importantly ensure complete adhesive coverage. Use a straight edge across each few rows to ensure the rows are exactly straight and parallel. After completing the area, remove the battens and fill in the gaps. If tiles with an irregular back are used, ensure to "butter" the back of the tile with adhesive so as to achieve complete adhesive coverage. Any cut tiles can also be "buttered" to make them easier to place. Cuts should be laid so that the uncut edge is adjacent to the other tiles.

3.3 Cutting the Tiles

A tile cutting machine for floor tiles should always be used. It is possible to cut them in other ways, but generally it is not very reliable. A tile cutting machine will make most reasonably sized cuts in most tiles. Simply place the marked tile in the machine, scribe firmly along the line, place the breaker wings on the tile and press down firmly.

When cutting a very small amount off the tile, scribe in the normal way, but then with very small nibbles, nip the rest of the tile away with the nippers. Notches and curves must also be nibbled away with a tile nipper. To make these shapes, it is best to use a cardboard template then very carefully, very slowly, with very small bits, nip the tile away.

3.4 Grouting

The procedure of grouting is done exactly the same way as wall tiles. It is important for floors to remove all the grout. Floor tiles are generally rougher in texture than wall tiles, so the grout takes more time to remove. Dark grouting is normally used in floors and can be messy if allow it to get onto other surfaces. Use masking tape to ensure this does not happen. To help prevent discolouring and cracking, it is vital to use grout mixed with flexible grout additive.

4.0 REMEDIAL

4.1 Retiling

There are numerous ways to solve the arching and lifting of the ceramic floor tiles at Cargo Agents Building 'C'. One way is to hack out the existing ceramic floor tiles and re-laid with new ones but taking into consideration the various points mentioned in Section 2.0 (Causes of Defects) and Section 3.0 (Good Practices).

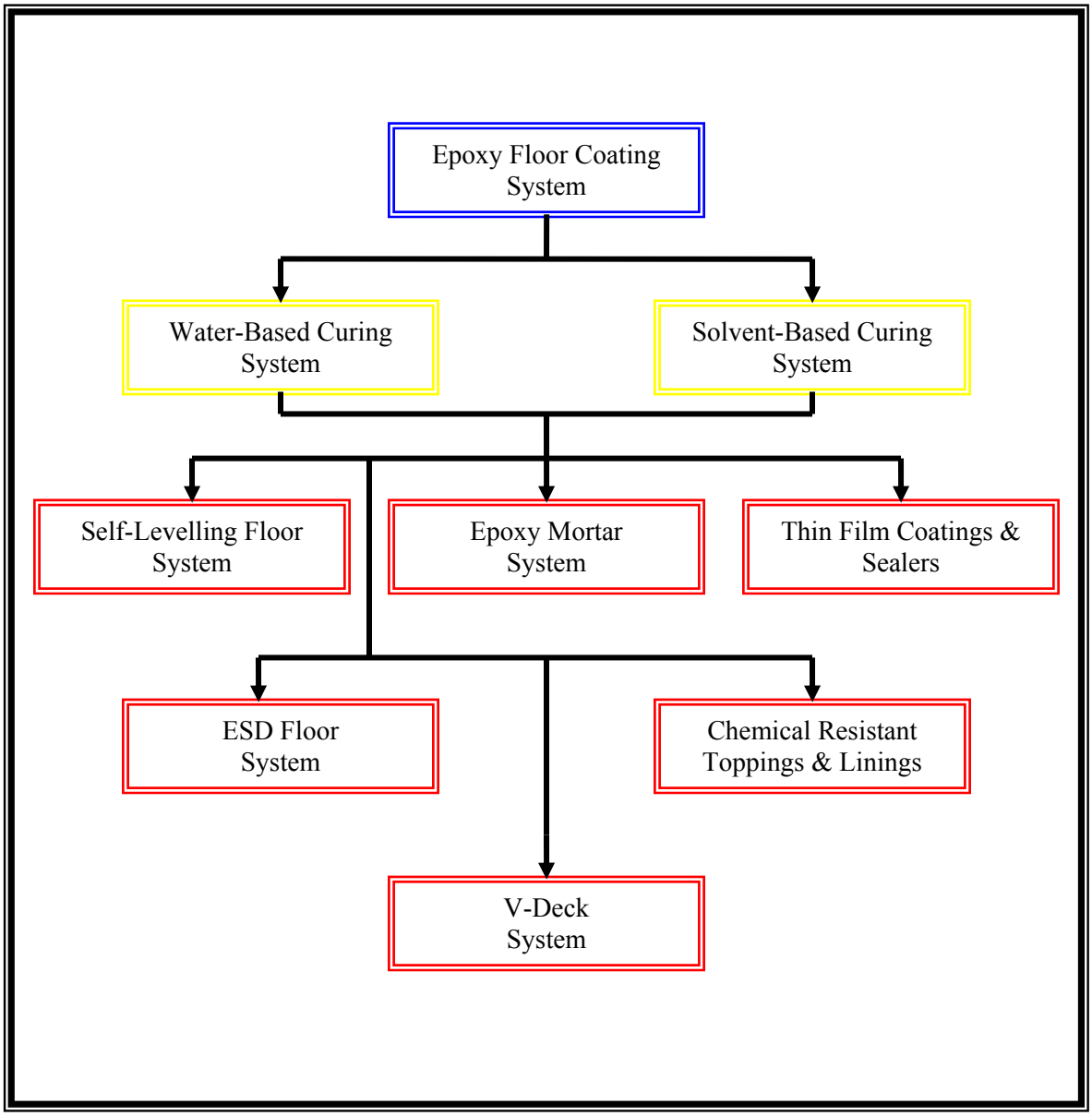
4.2 Epoxy Floor Coating System

Alternatively, replace the existing with new form of floor finishes. For this case study, Epoxy Floor Coating System is recommended as the alternative floor finishes for the main lobby. Generally, epoxy floor coating systems are classified under two main categories: Solvent-Based Curing and Water-Based Curing and under these two categories there are many types of systems available in the market (refer to figure 7). Some of the common epoxy floor coating systems includes:

- Self-levelling Floor System
- Epoxy Mortar System
- Thin Film Coatings & Sealers
- Electro Static Discharges (ESD) Floor System
- Chemical Resistant Toppings & Linings
- Vehicular Deck (V-Deck) System

The advantage of this system is that it provides a continuous floor coating system with no mortar joints and also provides a better bonding to the substrate.

Figure 7 - Types of epoxy floor coating system



The type of epoxy floor system to use depend on the type and usage of the area in question such as kitchen, hospital, staircase, workshops, lift lobby, corridor etc. For this case study, decorative epoxy floor coating system is proposed. It is a seamless, textured, decorative coating system on a synthetic resin base for light to semi-heavy loads which is ideal for main lobby which caters mainly to human traffic.

Figure 8 – Section view of the various layers of decorative epoxy floor coating system

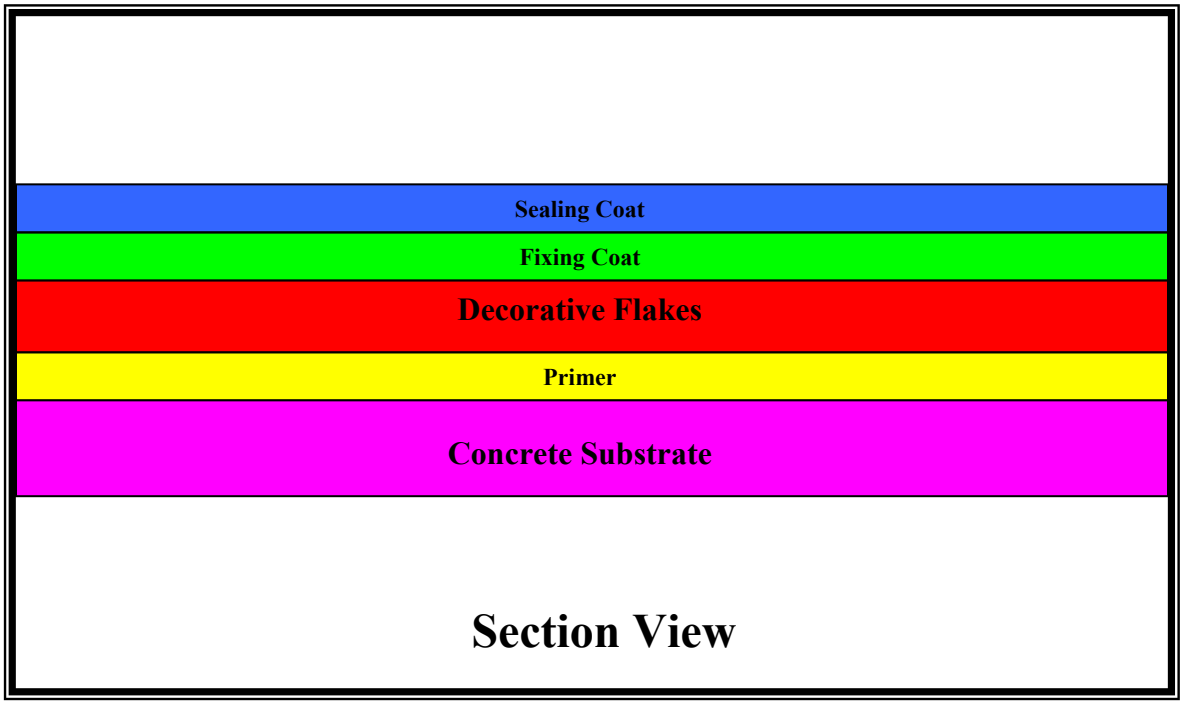


Table 1 and 2 provides a detail presentation of the Specification and Technical Data of the floor system. Photo 7 and 8 show a similar type of epoxy floor system used in Shell Tower ground floor.

Table 1 – Specification Data

Specification Data
Preparation Repair all hollow, damaged and ponding areas with higher strength chipping screed. The areas should be further prepared and clean by shot blasting method.
Priming Prime the prepared surface with sediment resin for bonding the sediment flakes to the substrate as advised by the manufacturer to yield minimum adhesion strength of $4N/mm^2$. It is a multi-purpose, transparent epoxy resin that is self-flowing thick coating. It has a compressive strength of $60N/mm^2$.
Resurfacing Immediately after the sediment resin adhesive layer is applied, sediment flakes that are PVAC materials are fully and evenly laid onto the fresh adhesive layer.
Sealing After the adhesive layer has cured, remove all excess sediment flakes. The entire surface to be sealed with sediment resin as a fixing layer and follow with PU sealant.

Table 2 – Technical Data

Technical Data	
UV Resistance (7 days ultra Vitalux)	No crack or yellowing
Shore Hardness	68 ^oC
Adhesion Strength	Minimum $1.5N/mm^2$
Crack Bridging	2mm
QUV Exposure at 340nm for 1000hrs	Min grey scale rating 4
Compressive Strength	Min $40/mm^2$
Slip Resistance (average) a) Coefficient of Friction (Dry) b) Coefficient of Friction (Wet) c) Coefficient of Friction (Wet with trition X-100)	 0.60 0.52 0.45
Abrasion Resistance	Max 55mg/1000cycles, loading 1000gm under cs17
Chemical Resistance (open spot test)	No effect after 16 hours exposure

a) 50% Ethyl alcohol b) 3% Vinegar c) Saturated lime solution (alkali) d) 40% Sulphuric acid e) Soap solution f) 10% Ammonia solution g) Vegetable oil h) Condiment (Chilli sauce) i) Beverage (coffee)	

Photo 7 – Epoxy floor coating at Shell Tower

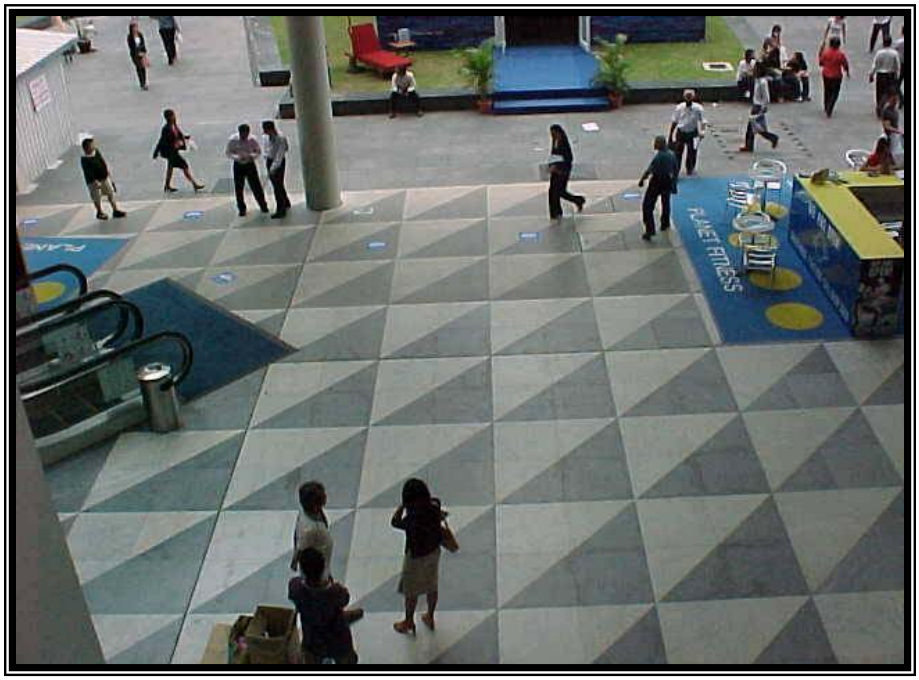


Photo 8 – Close-up view of the epoxy floor system

4.3 Assessment Framework

An assessment framework would be used in deciding on which remedial methods the maintenance team should used. Some of the key issues to be addressed by the maintenance team include:

- Should the management stick to the same type of floor finishes or to adopt new form of floor finishes?
- Which methods would solve the current maintenance problems faced by the management?
- Will the selected method create new problems in the future?

- In the long-run, which methods would gives a better return in terms of tangible benefits (e.g. maintenance cost) and non-tangible benefits (e.g. ease of maintenance)?
- Is the new method suitable for the main lobby? Will the image and aesthetic view of the main lobby be sacrifice if the new method is used?
- What is the one-time cost or implementation cost for each method? Is there a significant difference?

4.3.1 Retiling Versus Epoxy Floor Coating

Both methods have their merit and demerit points to consider. The management needs to consider each method individually before deciding on which methods to use.

Retiling Considerations

Unless the works are of good workmanship, proper supervision of the works is carried out and the works are carried out in accordance to the good practices for this type of work, the existing problems faced by the management would still resurface. This is especially important since money are being spend on the replacement works to solve the initial problems.

Epoxy Floor Coating Considerations

The main consideration for the epoxy system is the suitability of the system for the main lobby in terms of which types of epoxy system suit the usage of the area. As mentioned earlier, there are many types of epoxy system in the market. The management needs to

consider the best type of system to avoid over-specified or underspecified the type of epoxy floor system to adopt e.g. the minimum requirements such as the compressive strength, adhesion strength, slip and chemical resistance properties etc.

Table 3 – Retiling Versus Epoxy Floor Coating

S/no	Evaluation	Retiling	Epoxy Floor Coating
1.	Problems faced		
	a. Expansion Joint		
	- provision of expansion needed?	Yes	No
	- floor finishes would fail with the failure of the expansion joint	Yes	No
	b. Base Concrete/Screed		
	- any drying shrinkage of base screed problem?	Yes	No
	- thermal expansion problem?	Yes	No
	- absorption of moisture problem?	Yes	No
	c. Vibration		
	- would floor finishes fail due to structural movement or ground settlement?	Yes	No
2.	Aesthetic affected after repair work?	Yes	No
3.	Ease of Maintenance		
	- easy to repair?	Yes	Yes
	- easy to clean?	Yes	Yes
4.	Cost of implementation? note: based on estimated area of 145m^2 and quotations from suppliers	$20,000	$12,000

From table 3, it seems that using epoxy floor coating system would be more advantageous than retiling. Not only the new system would solve most of problems faced by conventional ceramic floor tiles system, it is also cheaper to implement without sacrificing the aesthetical as well as the maintenance considerations.

5.0 CONCLUSION

The Estate Management Section of Civil Aviation Authority of Singapore, after carrying out visual survey and preliminary investigation came out with the preliminary report and putting up the necessary approval paper to change the existing ceramic floor tiles at the main lobby with epoxy floor coating system.

The works were awarded to the contractor at \$74 /m^2 at a total cost \$ 11,988. The method statements of the works are attached in the Appendix. The detail breakdowns costs are as follow:

S/N	Description	Price (per m^2)
1	Hacking off existing floor tiles and cart away	\$ 5.00
2	Preparation Work	\$ 5.00
3	3mm thick epoxy colour quartz screed	\$ 34.00
4	Acolan Sediment System	\$ 30.00
	Sub-Total	\$ 74.00
	Grand-Total	**\$ 11,988.00**

Currently, the replacement works are still in progress. Hopefully, with the improvement, the epoxy coating would provide a consistent floor finishes with the same colour tone and enhance the aesthetic of the lobby and solving the problem of arching and lifting of floor tiles problem in the main lobby at Cargo Agents Building 'C', Changi Airfreight Centre.

METHOD OF STATEMENT
10MM THICK QUARTZ EPOXY SCREED
TO LIFT LOBBY AREA

PRODUCT DESCRIPTION

Viscacid Quartz Epoxy Screed is a solvent-free mortar which consists of Viscacid Epoxy Construction Resin combined with Viscacid Quartz Aggregate. It has excellent physical properties, such as a liquid impermeable finish that has inherent slip resistant qualities with a comprehensive range of chemical resistant values as well as a pleasing and attractive finish.

PRODUCT CHARCTERISTIC & PROPERTIES

The Viscacid Quartz Epoxy Screed shall comply with the following : -

PRODUCT CHARACTERISTIC & PROPERTIES	
Solid Content	100% by weight
Density	2.10 g/cm^3
Compressive Strength	80 N/mm^2
Flexural/Tensile Strength	17.50 N/mm^2
Adhesion Strength	3.90 N/mm^2
Abrasion Resistance (DIN 51963, average loss of thickness after twenty cycles)	0.043mm
Odour	None
Toxicity	Physiologically Safe
Thermal Resistance	0 - 80^0C
Loading Capacity - Foot Traffic - Full Strength	24 hours 7 days

METHOD OF STATEMENT
10MM THICK QUARTZ EPOXY SCREED
TO LIFT LOBBY AREA

SURFACE PREPARATION

1. The existing tile to be removed.

2. The entire surface must be cleaned, dried and free from contaminants such as dust, cement laitence, oil grease, paint and other materials which inhibit good adhesion

3. Any crack, depression, damaged and soiling area on the concrete floor must be identified and rectified.

PREPARATION REQUIREMENT

1. Prior to the application of theViscacid Quartz Epoxy Screed, the entire surface to be be further prepared.

APPLICATION PROCEDURE

1. Apply one coat of Viscacid Epoxy Construction Resin as primer to the prepared floor.

2. While the primer is still tacky, lay Viscacid Quartz Epoxy Screed of 10 mm to smooth finish.

3. Prime the prepared Epoxy Screed surface with Acolan Sediment Resin for bonding the Sediment Flakes to the substrate as advised by the manufacturer to yield minimum adhesion strength of $4N/mm^2$. It is a multi-purpose, transparent epoxy resin that is a self-flowing thick coating. It has a compressive strength of $60N/mm^2$.

4. Immediately after the Sediment Resin Adhesive layer is applied. Sediment Flakes is PVAC materials that are fully and evenly laid onto the fresh adhesive layer.

5. After the adhesive layer has cured, remove all excess Sediment Flake. The entire surface to be sealed with Acolan Sediment Resin and follow with the Acolan Arti Top Sealant.