MyConcrete

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MyConcrete:
The Bulletin of the American Concrete Institute – Malaysia Chapter

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CONTENT

EDITORIAL NOTE

In this 9th issue of this year "MyConcrete" bulletin., we take immense pleasure to publish this monthly official bulletin of American Concrete Institute – Malaysia Chapter (ACI – Malaysia Chapter). The bulletin publishes latest research and case studies conducted in academia and industries for the concrete industry professional.

This issue of MyConcrete presents the 1st technical commentary prepared by technical committee of ACI – Malaysia Chapter. The editorial team would take this opportunity to thank all who have assisted to make this very 1st technical commentary successfully. It addresses various water intrusion issues at the concrete roofs from the Malaysian perspectives. Testing and inspection process for water intrusion problem is discussed towards suggesting the remedial measures. The document can serve as a good reference for the construction industries and the practicing engineers. We would continue to seek and invite professionals and researchers to contribute concrete related articles for the upcoming issues of the bulletin.

The editorial team would like to thank Zacklim Flat Floor Specialist Sdn Bhd. for sponsoring this issue as a premium sponsor. We also would like to thank our loyal sponsor, Maiyer Craft (M) Sdn Bhd.

The sponsorship is open for upcoming issues and we hope to get more sponsorship in future.

Thank you very much. Happy reading.

Dr. A. B. M. Amrul Kaish
Editor, MyConcrete Bulletin

NOTE FROM MEDIA HEAD

Greetings concrete enthusiast! We are proud to present you the latest issue of MyConcrete bulletin. On behalf of American Concrete Institute – Malaysia Chapter, we would like to thank all the supports from our fellow member. On top of that, as the head of Media group, I would also like to personally highlight how much I appreciate the effort from the editorial team to provide us this monthly bulletin with such informative articles and event updates. With the effort of the entire ACI Malaysia team, our bulletin this month will be slightly different. We all joyful and grateful to announce that we are starting to offer a platform for our ACI student member to seek for their internship while industry member could post up for internship hiring. With this effort by ACI Malaysia, we hope that we could narrow the gap between students and the industry by allowing them to be exposed to "practical concrete" rather than just "theoretical concrete" from their academy. Nonetheless, the other effort that we are proud to announce this month is our VERY FIRST technical commentary; "Water Intrusion Issues At Concrete Roofs". By our very own selected technical committee, we summed up issues that are faced and the common causes. Despite of just highlighting the water intrusions problems, we also include practical methods to test and more importantly, the remedial methods and their considerations. Hence, I would like to take this opportunity to thank the Selected Technical Committee that was led by Mr. James Lim and the other committee members. Apart from showing our gratitude to the contribution of the technical report, we must also thank our fellow sponsors for this month's successful sharing. Our premium sponsor of the month is ZACKLIM FLAT FLOOR SPECIALIST SDN.BHD. They specialize on super flat floor for example for warehouse usage, industrial flooring or car parks. Furthermore, our loyal sponsor this month is MAIYER CRAFT (M) SDN. BHD. They provide solutions to various finishes of flooring. Without such sponsorship, we will not have been able to launch and share another successful bulletin. To all members, we are continuously seeking for your sharing and contribution. Do contact our admin shall there be any enquiry. Once again, we like to sincerely thank all our contributors and also the media team together with the editorial team for another month of successful sharing. The pandemic is yet to be endemic. We also like to urge everyone to stay safe, follow the required S.O.P and bring our nation back on the right track. Together, we can.

Oscar Teng
Head of Media Committee

INTRODUCTION TO ACI MALAYSIA CHAPTER

American Concrete Institute - Malaysia Chapter (ACI-Malaysia) is a non-profit technical and educational society representing ACI Global in Malaysia, which is one of the world's leading authorities on concrete technology. Our members are not confined to just engineers; in fact, our invitation is extended to educators, architects, consultants, corporate, contractors, suppliers, and leading experts in concrete related field. The purpose of this Chapter is to further the chartered objectives for which the ACI was organized; to further education and technical practice, scientific investigation, and research by organizing the efforts of its members for a non-profit, public service in gathering, correlating, and disseminating information for the improvement of the design, construction, manufacture, use and maintenance of concrete products and structures. This Chapter is accordingly organized and shall be operated exclusively for educational and scientific purposes.

Objectives of ACI-Malaysia are:

- ACI is a non-profitable technical and educational society formed with the primary intention of providing more in-depth knowledge and information pertaining to the best possible usage of concrete.

- To be a leader and to be recognized as one of Malaysia's top societies specializing in the field of concrete technology by maintaining a high standard of professional and technical ability supported by committee members comprising of educators, professionals and experts.

- Willingness of each individual member/organization to continually share, train and impart his or her experience and knowledge acquired to the benefit of the public at large.

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i) ACI Malaysia is only a platform for our members to advertise for interns.

ii) All application to be made direct to companies and would be subject to their terms and conditions.

UP COMING EVENTS

Free Webinar - The Tech-Talk Hour

Speaker: Mr. Lim Kean Meng

Topic: Defects & Failures in Polymers Floors

Date: 9th December 2021

Time: 8:30pm - 9:30pm

For more info: www.acimalaysia.org

See you live at: facebook.com/acimalaysia.org

PRECEDING EVENTS

TECHNICAL COMMENTARY No. 1

WATER INTRUSION ISSUES AT CONCRETE ROOFS
- The Malaysian State of Affairs

Developed by:

Select Technical Committee,
American Concrete Institute – Malaysia Chapter

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1.0 FOREWARD

The problem of water intrusion leading to leakage in concrete roofs is of great concern and interest to many stakeholders and building owners in Malaysia. In view of this, American Concrete Institute-Malaysia Chapter (ACI Malaysia) undertook to develop this Commentary through the joint/collective effort and contribution of various practitioners who are knowledgeable/experts and experienced in their respective related field. In general, this Commentary focuses on the current practices in Malaysia pertaining to the design, construction and repair of waterproofing systems on concrete roofs of buildings. The development of this Commentary is in line with the primary objective of ACI Malaysia to share, enhance and advance knowledge in concrete technology.

This is ACI Malaysia's first Commentary, and feedback from various industry practitioners and other interested parties towards the published information in this Commentary is welcome. The feedback will be considered for future improvement on practices and issues relating to waterproofing in buildings. It is hoped the construction industry and owners will find this Commentary beneficial and useful in their pursuit to resolve issues relating to waterproofing in concrete roofs.

2.0 ACKNOWLEDGEMENT

This Commentary has been developed by members of a Select Technical Committee of ACI Malaysia who have related knowledge and experience and include members of a NGO, design engineers, architects, applicators, a developer, contractor, supplier, academician and a lawyer. We in ACI Malaysia gratefully acknowledge and appreciate the following members of the Committee for their valuable efforts and contribution of knowledge to make this Commentary possible.

Members of the Select Technical Committee.

1. Mr. James Lim Khin Fong	CRT Specialist (M) Sdn. Bhd. *(Managing Director)* ***Chairman – Technical Select Committee***
2. Professor Dr. Hamidah Bt. Mohd. Saman	Research and Industrial Linkages UiTM *(Deputy Dean)* ***Secretary – Technical Select Committee***
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4. Mr. Tee Eng Tiong	Kerjaya Prospect (M) Sdn. Bhd. *(Project Director)*
5. Mr. Mu Kanesan	M. Kanesan & Associate Advocates and Solicators *(Principal)*

Special thanks to Mr. Lim Kean Meng Technical Manager of Mapei Malaysia for his contribution on “Zero Span” Tensile Stress Effecting Waterproofing Membranes.

Martin David
The President (2020 - 2022)
American Concrete Institute - Malaysia Chapter

3.0 SCOPE AND OBJECTIVES

The requirements for proper and effective waterproofing systems are often not well understood or managed poorly, resulting in many problems related to unacceptable leakages of moisture through the concrete roof. This Commentary has been prepared to cover the various aspects of design and construction of concrete roof waterproofing systems including problems of water leakage and their causes, design and construction considerations, testing and inspection, responsibility of parties involved, common crack repair methods and some proposed recommendations for consideration.

The main objective of this Commentary is to create better awareness and understanding of the current practices and procedures in design, construction and defect management of waterproofing systems so that leakages through a concrete roof can be prevented or minimised. Most importantly, stakeholders would gain a better insight of the essential requirements and pitfalls to be avoided in carrying out an effective waterproofing system. Some suggestions to further improve and enhance the current practices are also put forward for consideration.

Any feedback to further improve waterproofing systems would be most welcome. It is the hope of ACI Malaysia that this Commentary would, in one way or another, be helpful and beneficial to all stakeholders and owners of buildings with a concrete roof top, particularly in identifying any shortfall in present waterproofing practices.

4.0 INTRODUCTION

More and more multi-store high-rise buildings are being built all over Malaysia these days. Most of them are constructed with a flat reinforced concrete (RC) roof mainly because they provide safe, easily accessible flat platforms for various items to be installed such as mechanical, electrical, and telecommunication equipment, water tanks and other utilities. For condominiums, these platforms can be used for recreational activities such as a swimming pool and a playground. Being on the top, these roofs are exposed to all sorts of weather conditions, which can be severe especially in a tropical country like Malaysia. Heavy rainfall can lead to water staying stagnant on the roof for a long period. The Uniform Building By- Laws 1984, Part VI, Clause 84 item (1), states that “Suitable measures shall be taken to prevent the penetration of dampness and moisture into a building.” Therefore, it is imperative that a proper and effective waterproofing system is put in place to prevent unacceptable infiltration of water into the concrete slab and space below.

Concrete is inherently porous and it is almost impossible to make it totally impermeable. However, a “sealer” (skin or membrane) can be added on the top of it to prevent water penetration. For this Commentary, a waterproofing system for a RC roof shall include the concrete slab and the top waterproofing skin or membrane (referred to as liner) that act together to prevent water intrusion into the roof and the finished space below. Please refer to Figure 1, item 7.0, for a detailed illustration of a flat roof waterproofing system. In essence, both the concrete slab and the waterproofing liner must be adequately designed, constructed and maintained to ensure the watertightness requirements of the roof. There are various types of liners available and designers need to select the best type in terms of performance under the conditions at the site.

In general, the basic design of a waterproofing system (i.e. RC Roof Slab and Waterproofing Membrane) for water tightness should incorporate three (3) steps as follows:

- Identify water sources, structural and environmental loadings;
- Design a waterproofing system to suit the expected loadings and prevent potential leakage (including selection of materials and structural design);
- Finalize the design by properly detailing all components required for construction

5.0 WATER INSTRUSION PROBLEMS AND COMMON CAUSES

5.1 ISSUES AND PROBLEMS

A RC flat roof can experience issues relating to water seepage if it is not designed and constructed properly. In fact, this is a common problem in many buildings in the country. These leakages, when they occur, will cause a lot of inconvenience to the occupants below, with unsightly stains and even damage to the ceiling and walls including the finishing, fittings and furniture. Long term leakage will also cause weakening and deterioration of the RC slab which can eventually affect its structural integrity if timely repairs are not carried out.

In a tropical climate like Malaysia, the roof is constantly exposed to scotching heat, fluctuations in temperatures and frequent heavy rainfall. Very often the roof slab needs to support heavy loads from various installations such as mechanical and electrical components and systems, and water tanks. Owing to heavy loading and harsh exposure conditions,a RC roof waterproofing system is at risk of leakage especially if it is not adequately designed, constructed and maintained.

Water leakage in a RC roof can be due to one or several possible causes and it usually occurs several years after completion of the building. Often the cause(s) and parties responsible are very difficult to establish, leading to disputes that may take years to resolve. The defects causing the leakage can be linked to the responsibility of an individual or more parties, ranging from the architects, consultants, waterproofing subcontractor, main contractor as well as product manufacturers. In addition, property developers cannot be ruled out as well in the discussion of defect responsibility as they possess veto powers that could influence the product selection process in a new development project.

Generally, failure of a waterproofing system may occur a few years after completion by which time the defects liability period of the developer may be over and the waterproofing applicator is left to remedy the problem. The applicator may have given a warranty to the developer, but if the leakage is due to damage of the waterproofing caused by structural movement, the warranty cannot be enforced. This, then leaves proprietors with the financial burden of seeking a solution to carry out the necessary repairs.

5.2 COMMON CAUSES

The degree of water tightness of a RC roof waterproofing system depends on the ability of the concrete slab and top liner to prevent water intrusion into the ceiling below. The main cause of water leaks is seepage of water through cracks in concrete roof slabs. It is often said that the watertight skin “fails”; this is a grave misconception, as in ACI 201.1R-08 (under Appendix Item 3) states it is a distress indicator. This means that through-cracks in the RC roof slab have occurred. The causes of cracking in a RC roof include:

- high thermal movement
- lateral movement due to active and transient loads
- excessive structure deflection
- poor detailing
- short and long term shrinkage (creep)
- poor materials and workmanship

Another misconception is that the watertight skin is elastic (eg.300% elongation) and the crack bridging property (e.g. 2.5mm wide) should mitigate this. This is probably correct if say a, 1mm crack exists before the application of the watertight skin. The two properties mentioned above will be activated, as there is a 1mm span for crack bridging and thus elongation can manifest.

However, if cracks develop after application or post application, these properties cannot be activated because of the Zero Span phenomena (refer, ***1***. applied sciences article from Seoul National University of Science and Technology**,** ***2***. ACI 515.2R – 13 page 16, section4.11 paragraph 2**,** ***3***. Ardex Technical Bulletin-TB073, Misconceptions About Membrane Elongation).The force which induces the concrete to crack will also tear the watertight skin, thus breaching the watertight skin, and allowing water to leak through the crack.

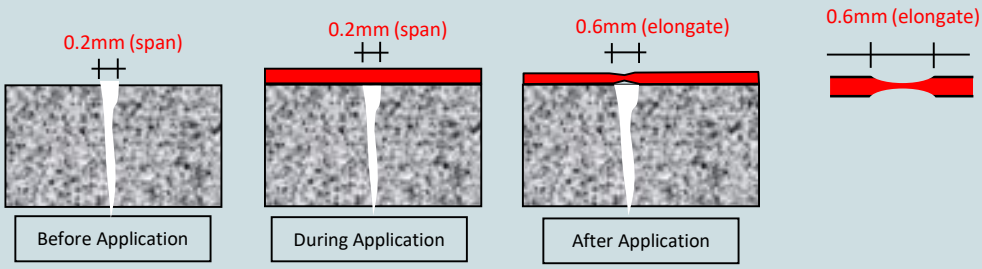
Photo 1:
Cracks at soffit of slab with stalagmite formation due to leaks

Photo 2:
Cracks at soffit of slab with cracks size of 1.2mm wide

Photo 3:
Cracks at soffit of slab with cracks size of 0.6mm wide with rust stain from corroded rebar.

Illustration of cracks occurring before and after (Zero Span Phenomena) waterproofing membrane application:

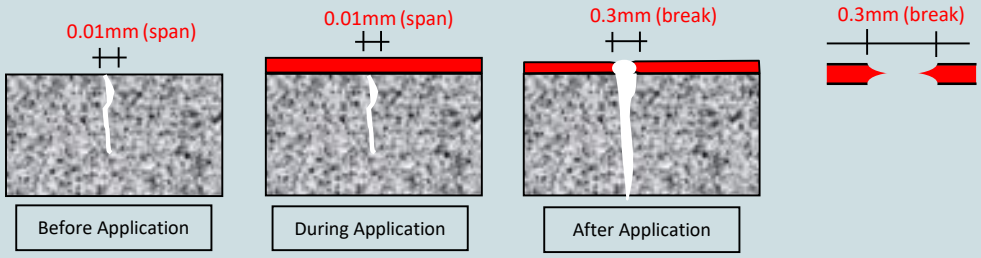
Example 1: *Cracks existing before application of waterproofing system (properties 300% elongation and crack bridging)*



Elongation = $\frac{(0.6mm - 0.2mm)}{0.2mm}$ x 100% = 200% (of elongation is required in waterproofing system)

- Elongation required to treat crack is 200%. This is within 300% elongation property mentioned. Therefore membrane will not tear.

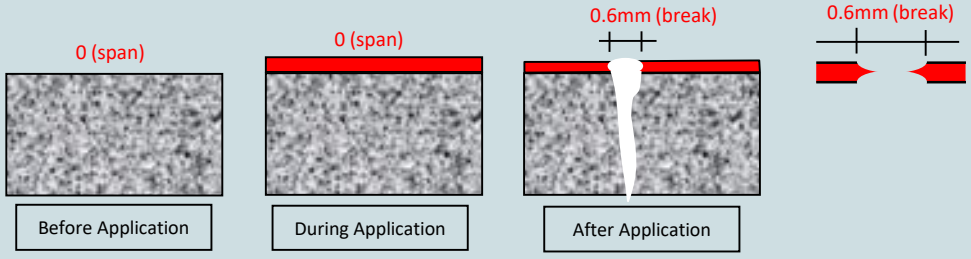
Example 2: *Cracks existing before application of waterproofing system (properties 300% elongation and crack bridging).*



Elongation = $\frac{(0.3mm - 0.01mm)}{0.01mm}$ x 100% = 2900%

- Elongation required to treat crack is 2900%, this doesn't meet the 300% stated. Therefore membrane will tear. Also note that all known membranes in the industry from the elongation property standpoint will also not comply to the 2900 % requirement. Possibly some other property may overcome this 2900% requirement.

Example 3: *New cracks after application of waterproofing system (properties 300% elongation and crack bridging) - Zero Span Phenomena.*



Elongation = $\frac{(0.6mm - 0)}{0.0mm}$ x 100% = 0% or Infinity %

- Elongation required to treat crack is Infinity%, this doesn't meet the 300% stated. Therefore membrane will tear. Also note that all known membranes in the industry from the elongation property standpoint will also not comply to the Infinity% requirement. Possibly some other property may overcome this Infinity% requirement.

6.0 Information for Consideration

6.1 Introduction

The Standard Design Practise for reinforced concrete roofs in Malaysia is based on BS EN 206/BS EN 1992-1 (previously used BS 8110). These standards are very wide and the understanding of the function of the reinforced concrete roof must be clearly remembered. The roof could be used to house mechanical and electrical equipment or as recreation space, but what is common is that it must prevent the water from penetrating into the building.

The Waterproofing system at the roof slab is made up of a few elements such as the concrete slab, waterproofing skin (or liner), insulation board(optional) and protective screed or tiles.

Drawings and specifications should be prepared in sufficient detail by the designer to provide proper guidance to the Implementation of Waterproofing System by the Construction Team to reinforced concrete roofs and wet areas. It is also important to ensure the compatibility and bonding performance of the membrane to the concrete roof substrate.

The structural, architectural and M & E drawings affecting the RC roofs should be reviewed together for reliability of the waterproofing system and to ensure consistency in dimensions (e.g. final thickness of the floors, M & E configurations, etc.). There should also be a good level of awareness and understanding of the structural system being used (e.g. precast hollow core slab system, cast in situ RC system, etc.).

6.2 Design Considerations

In Reinforced Concrete Design, Engineers could adopt the following standards (as per Standard Design Practise)

6.2.1 Selection of proper structure section and exposure class to comply its usage - BS EN 206/BS EN 1992-1: PT 7 SLS

6.2.2 ULS requirements for shear/bending/torsion. – BS EN 1992-1:PT3.1.6

6.2.3 Minimum reinforcements are required for compression for crack control – BS EN 1992-1:PT7.3.2

6.2.4 Compliance to the required deflection under SLS – BS EN 1992-1:PT 7.4

6.2.5 Design to the required crack width of 0.3mm to its usage, exposure class: XC4 and XF3 – BS EN 1992-1:PT7.3.4 (depth of crack not mentioned)

6.2.6 Thermal control, long term creep and drying shrinkage checks under – BS EN 1992-1: PT 3.1.4 and CIRIA C660. (Additional reinforcements by design will be needed for this service limit control.)

6.2.7 Concrete compressive strength range C32/40 t0 C40/50 and cover range 25mm to 30mm – EN 206/MS 523-2/BS 8500-1.

6.2.8 Pull Off strength to receive waterproofing systems is 1.5N/mm2.

It is well acknowledged that cracks passing through the thickness of a slab section (“through cracks”) are detrimental to the waterproofing of the reinforced concrete roof. These “through cracks” developing after the application of the waterproofing lining will damage the membrane by tearing it (zero span phenomena).

For crack width and depth design one could also consider using EN 1992-3 (previously used BS 8007): PT 7.3.1, Tightness class 2 (crack width 0.2mm) and 3 (crack width 0.1mm) and avoiding cracks to pass through thickness of slab section. This is a more Stringent Design Practise.

Another consideration to overcome shortcomings (if any) in the design, material, workmanship, etc; are steel and polymer fibres. These fibres normally act as a crack arrestor to prevent the cracks from propagating. The codes and standards to refer to are EN 14889-1&2, ACI 544.4R-

88, ACI Materials Journal Title no.87-M16. As an indication, 10 to 20kg of steel fibre per meter cubic of concrete will control a crack width from 0.1 to 0.2mm (refer to above mentioned journal, Figure 11, page 144). However, this is subject to the structural engineer's design.

RC slabs should be laid to fall as a good practise. However, if there are through cracks, water will run into these cracks and leak in its runoff process. Power-floating large slabs to a smooth-finish in order to mitigate plastic-cracks may be considered, to ensure consistent thickness of liquid applied waterproofing skin and also to provide a dense surface compaction.

The properties of the various membrane types are presented in item 6.5 Table 1 for material comparison in relation to RC roof waterproofing selection. The data presented in the next table has been extracted from product manufacturer's data sheet and is used to illustrate the various materials performance respectively.

6.3 Concrete Requirement

All concrete should comply with EN 206 Concrete Specification, performance, production and conformity requirements. The concrete should consider the following criteria:

1. Exposure class
2. Service life of structure
3. Concrete cover
4. Binder type
5. Water/binder ratio

Photo 4: Green Concrete

For illustration:

1. Structural Element: RC Flat Roof
   a) Service life: 100 years
   b) Concrete cover: 30 mm
   c) Exposure: Moderate humidity or cyclic wet and dry (XC3/4). External reinforced and prestressed concrete surfaces sheltered from, or exposed to, direct rain
   d) Waterproofing: Yes

According to MS 523-2/ BS 8500-1, the concrete should be designed as **C40/50**.

2. Structural Element: RC Flat Roof
   a) Service life: 50 years
   b) Concrete cover: 25 mm
   c) Exposure: Moderate humidity or cyclic wet and dry (XC3/4). External reinforced and prestressed concrete surfaces sheltered from, or exposed to, direct rain
   d) Waterproofing: Yes

According to MS 523-1/ BS 8500-1, the concrete should be designed as **C32/40**.

In the event where the watertightness is critical, the concrete exposure class may be assumed as XD1 or XS1.

6.4 Insulation Boards

It would be useful to have insulation boards as they would help maintain a consistent temperature and generate energy savings in any habitable unit below.

Cement sand screed, cut in a 2m x 2m panel can be used as a protective screed to prevent the watertight skin from damage due to ultra violet light and mechanical abrasion. Since the protective screed is just sitting above the waterproof membrane without restraint, the cement sand screed is expected to crack. Nevertheless, such cracks on the protective screed will not be detrimental to the waterproofing system that sits below. An efficient rainwater run off at the roof is important to ensure that no water is stagnant after a rainfall. The protective screed should have a minimum fall of 1:200 and this screed should be checked to eliminate stagnant water after completion of the floor screed

COMPARISON AND OPTIONS FOR CONSIDERATION										
NO.	Typical Properties	LIQUID APPLIED MEMBRANES (LAM)						PREFORM MEMBRANE		
		Standard Range			Medium Range		High Range	Standard Range	Medium Range	High Range
		Flexible Polyurethane	Flexible Acrylic	Flexible Polyurethane – Bitumen Hybrid	Flexible Cementitious – Reinforced	Hybrid Polyurea	Pure Polyurea	Bitumen Membrane	TPO Membrane	PVC Membrane
1.	Thickness	1.8mm	1.2mm	1.2mm	2mm	2mm	2mm	4mm	1.5mm	1.5mm
2.	Static Crack Bridging	Not Mentioned	Not Mentioned	Not Mentioned	0.5mm (EN1062-7)	2.5mm (EN 1062-7)	2.5mm (EN 1062-7)	Not Mentioned	Not Mentioned	Not Mentioned
3.	Dynamic Crack Bridging	Not Mentioned	Not Mentioned	Not Mentioned	0.1 to 0.3mm (EN 1062-7)	Class B4.2 (EN 1067-7)	Class B4.2 (EN 1067-7)	Not Mentioned	Not Mentioned	Not Mentioned
4.	Elongation	320% (DIN 53504)	200% (DIN 53504)	8000% (ASTM D412)	30% (DIN 53504)	400% (ISO 37)	300% (ISO 37)	40% (UEatc)	15% (EN 12311)	12% (EN 12311)
5.	Tear Resistance	Not Mentioned	Not Mentioned	1.08N/mm^2	Not Mentioned	45N/mm^2 (ISO 37)	80N/mm^2 (ISO 37)	400N, (ASTM D 5147)	350N, (EN 12310-2)	200N, (EN 12310-2)
6.	Zero Span Resistance	Not Mentioned	Not Mentioned	Not Mentioned	Not Mentioned	Not Mentioned	Not Mentioned	Not Mentioned	Not Mentioned	Not Mentioned
7.	Application	Roller, Trowel	Roller, Trowel	Roller, Trowel	Trowel	Spray	Spray	Torch On Fully Bonded	Loosely laid screwed fasten and hot weld at joint	Loosely laid screwed fasten and hot weld at joint
8.	Tensile Strength	1.5N/mm^2	1.25N/mm^2	2N/mm^2	20N/mm Bothway	12N/mm^2	25N/mm^2	Torch On Fully Bonded	Loosely laid screwed fasten and hot weld at joint	Loosely laid screwed fasten and hot weld at joint

6.6 Photos of Waterproofing Skin (or Liner)

Photo 5:
Liquid applied membrane (LAM)

Photo 6:
Reinforced Flexible Cementitious

Photo 7:
Hybrid Polyurea

Photo 8:
Pure Polyurea

Photo 9:
Preform Bitumen Membrane

Photo 10:
Preform TPO Membrane

7.0 Diagrammatic Illustration of Total Waterproofing System.

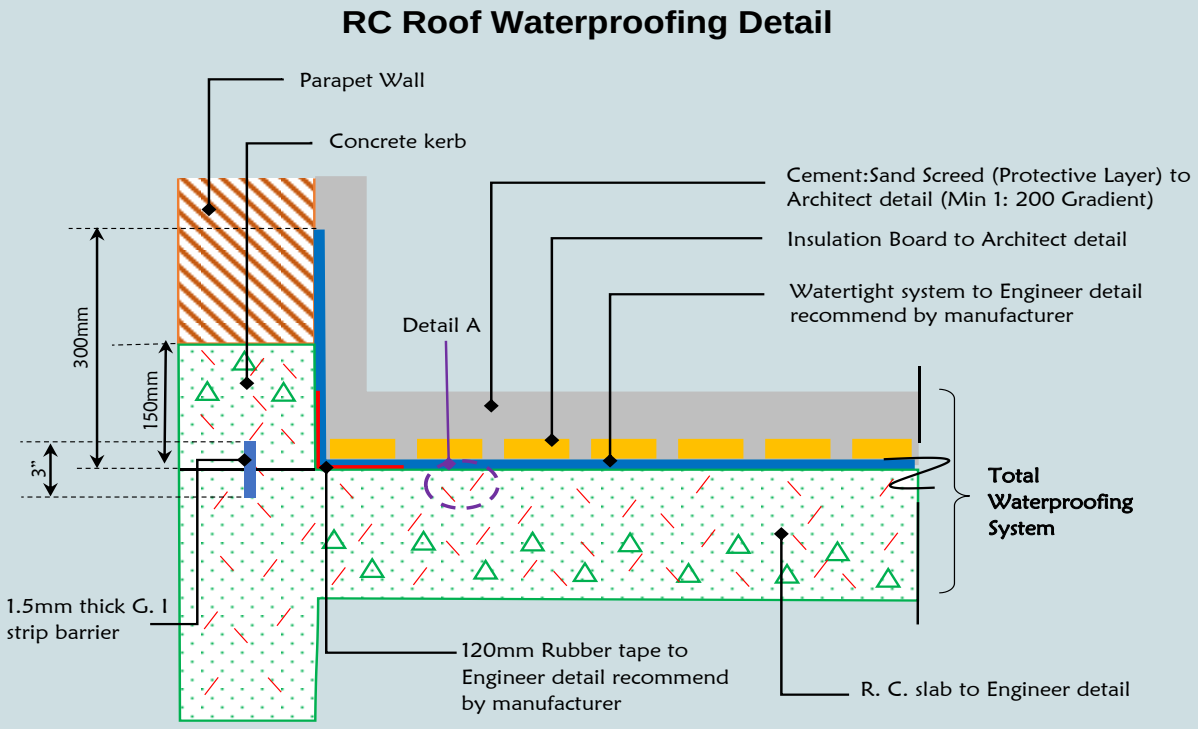
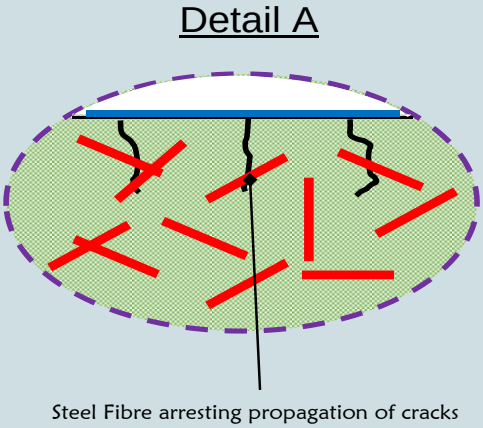


Figure 1



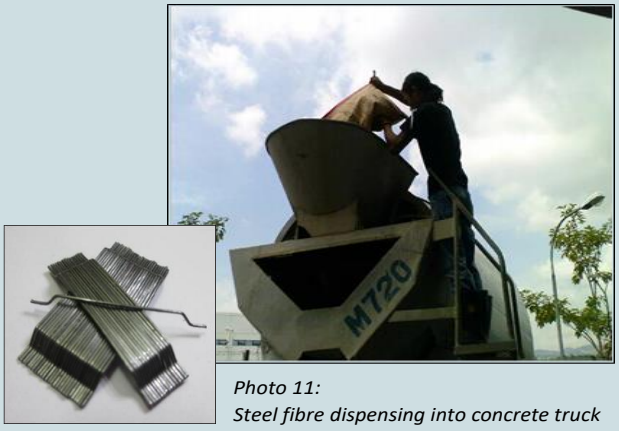


Photo 11:
Steel fibre dispensing into concrete truck

8.0 Testing And Inspection

8.1 Overview

Proper testing and inspection methods are necessary as per codes, standards and practices of the industry. However, the industry has now been introduced to various leak detection methods. Caution must be exercised in the use of such methods as the findings are often not conclusive.

8.2 Codes, Standards and Practices for Consideration

a) Lab Test:
In general, the 30 minutes water absorption of the concrete can be limited below 4% when tested according to BS 1881-122.

Also, the German Standard DIN 1048 can be used to check if the concrete is watertight. As a brief description of test, 5 bars of pressure to be exerted on a 28 day old 150mm x 150mm concrete cube made from concrete supplied. The pressure is to be maintained for 72 hours after which the cube is broken into two to determine visually the depth of water penetration. The result is recommended to be 30mm depth (refer to DIN 1045 for result criteria).

b) Site Test: Water ponding and visual inspection.
- CIDB CIS 7-2014: Part 2- External Finishes, General Requirements item 1(vi), No sign of Leak, Assessment Method, Visual.
- BS 8007:Section 9.3 Testing of Roofs: pond water to a minimum depth of 25mm for 24 hours and then check for leaks. Where impracticable, have water applied by a continuous hose or sprinkler system to provide a sheet flow of water over the entire area for not less than 6 hours and then visually check for leaks.
- ASTM D 5957 – 98: 7.6, Flood segmented area with potable water to achieve a minimum of 25mm depth and not exceeding 100mm at low point of test area. Do not exceed 65mm for mean water depth.7.10, Flood Test period should be minimum 24 hours and maximum 72 hours.7.12, provide constant monitoring during full duration of the flood test. Document conditions observed below the test area before beginning the flood test and at four hours intervals until completion of flood test.

c) Site Inspection:
- The practise of using as-built drawings to mark the cracks indicated by the leaks would also assist in early identification of the stresses being induced on the slab.

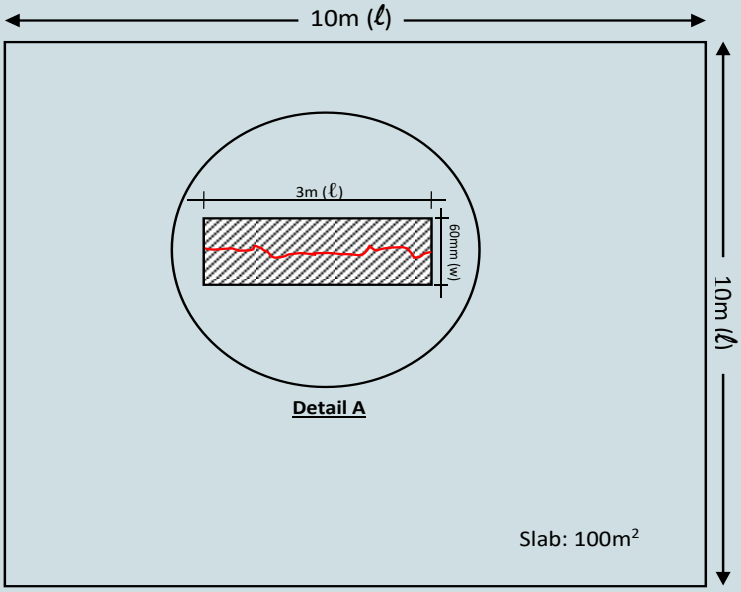
8.3 Allowable Limits for Non Structural Cracks

a) As cracks are inevitable due to extreme weather conditions, movements, etc., a recommended allowable limit (in terms of percentage) in relation with water leaks should be established. This allowable limit should be considered as acceptable wear and tear, and repairs should fall under maintenance works.

b) The recommended percentage is 5% of the area of the slab. The calculation of the water leak area should be the length of the crack multiplied by 60mm Wide (30mm on each side of crack) and then divided by the area of the slab. The cracks could be mapped out from the soffit of the roof slab post construction to establish the extent of the defects and to calculate the percentage of water leak at the roof slab to check whether it is within the allowable limit.

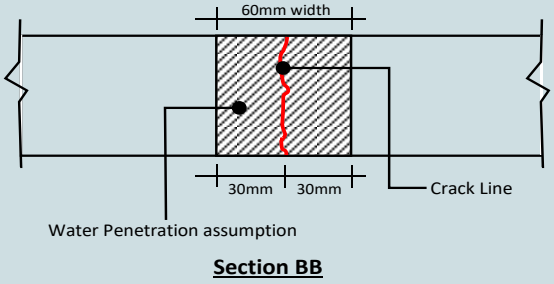
c) The 60mm value is arrived from 3.1 item(i) last line (Assuming 30mm penetration of water on each side of the crack).

8.4 Calculation for Allowable Limits for Non Structural Cracks

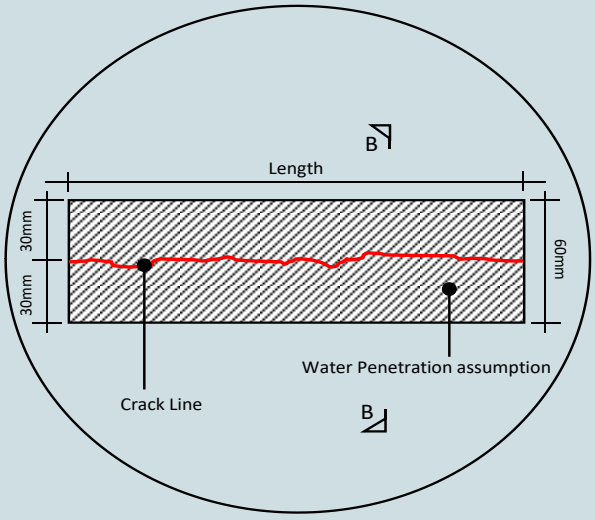


Detail A

Plan View



Section BB



Detail A

Calculation

3m(ℓ) x 0.06m(w) = 0.18m²

∴ % of Leak Area = $\frac{0.18m^2}{100m^2}$

= 0.0018m² or 0.18%

Conclusion: leak area is within 5% limit
Therefore, considered wear and tear

9.0 Collective Responsibilities for Consideration

The responsibilities can be divided into 3 groups of Stakeholders as follows:

9.1 The Design Team

- Developer
- Architects
- Engineers

The Architect and Structural Engineer should consider advising the Developer of the various options available to watertight the reinforced concrete roof. Matters in section 6 are a good platform to communicate to the Developer. The coverage of problems and possible solutions are mentioned briefly but clearly for consideration. Should detail technical discussion be carried out effectively, the water leak problems of the reinforced concrete roof will be very much reduced.

9.2 The Construction Team

- Main Contractor
- Waterproofing Contractor
- Material and Technology Supplier

As today's waterproofing systems are very advanced and most of the research and development is done in-house with the Material and Technology Supplier, it is critical for the supplier to share the material shortcomings (if any) during design stage; if this has been missed at least it should be done, early in the construction stage. Steps can then be taken to overcome these shortcomings. Suppliers should share their knowledge with the industry on this.

The Main Contractor and Waterproofing Contractor have to try their level best to keep to good practices. They may face challenges such as a lack of skilled labour, a shortage of labour etc. However, they have the "hands on experience" and should advise when they feel certain details or designs are not efficient instead of "do first, see later" solution. By doing this defect works will surely be reduced.

9.3 The Users

- Property Owners

Property owners should first approach the Developer if leaks appear inside a parcel and try to work out a solution with the Developer.
Should the design and execution be in accordance with all relevant codes and good practices, and defects still occur but within 5% limit of the waterproofed element (measured in terms of area), this should be accepted as rectifiable defects of the construction, to be categorised as maintenance works.

L0.0 Remedial Methods for Consideration

10.1 Overview

As mentioned in section 5 most of the time the waterproofing skin does not fail in total but rather gets damaged due to various reasons also discussed in section 5. Most of the time there is no need to replace the waterproofing skin but just repair it and elements associated with it. With the advancement in the construction industry and with construction chemicals, viable options are available and deserve consideration.

10.2 Leaks at Non Structural Cracks

a) Pressure Grouting (Injection) Method Using Polyurethane Resin (*BS EN 1504 part 5 and 9)*

Injection is the most commonly accepted method of repair when it comes to water leaks. It is a quick and reliable method of repair and it is effective in resolving water leaks through a concrete slab in the case of a flat roof or internal wet areas.

The injection resin seals the annular spaces inside the concrete so that the water flow path is closed by filling it with polyurethane (PU) resin. PU resin reacts with water inside the cracks or cavity to form a tough and rigid material that is bonded to the sides of the concrete in that annular space. Once the resin has filled that empty space either in a construction joints or surroundings of a pipe penetration, the water path is closed and water leakage is stopped.

An injection method allows sealing work to commence at the negative side of the waterproofing system. The negative side is always the side where water is leaking out. For underground structures such as tunnels and basement structures, injection is the standard method used to seal water leaks since there is no access to the positive side of the structure. This method of sealing has been widely used in underground projects around the world.

For injection to work, the selection of the injection resin, type of pumps and method of drilling the hole will determine the outcome of the injection work. The injection resin should have the following properties:

1. Resin foaming factor < 5 times. The higher the foaming factor, the lower its compressive strength.
2. Resin should be of a 2 components type and will set on its own without adding water. This is unlike most foaming polyurethane foam where water is required to start its foaming reaction. The foaming PU resin typically has a foaming factor of more than 20 times and the foam can shrink over time if the resin solvent content is high. High foaming PU resin is not recommended for injection sealing.
3. Unrestrained cured resin compressive strength > 30 MPa. This is an important criteria as the injection resin is injected into the concrete slab that has a compressive strength of 30 MPa and above.
4. Adhesive strength (wet surface) – Min. 1.5 N/mm2.

A good injection resin should have a minimum compressive strength of 30 MPa as it matches the strength of the concrete element. The adhesive strength of the PU resin is an important criteria as the injected resin bonds the cracks together and withstands higher water pressure due to a better bond.

For hairline or fine cracks that are < 0.2mm width, it is possible to seal the cracks with PU resin. To check whether resin can penetrate the hairline cracks, water is injected into the hairline cracks through a drilled hole. If water can pass through the hairline crack, then injection is possible.

For injection, an injection pressure of 1500 psi is recommended to start the injection. The pressure will drop to between 200 to 500 psi once the PU resin starts to penetrate the

crack/cavity. An injection pump should be used with a pressure regulator so that the injection pressure is maintained throughout the injection process. A manual control mechanism of the drill pump is not recommended to be used for injection as it is difficult to maintain the required injection pressure with a hand.

Holes are normally drilled at a 45 degree angle to intercept the cracks or cavity. Besides, the holes are normally staggered at both sides of the cracks to connect the drilled holes. Accessories normally referred to as an injection packer connects the injection pump and the cracks/cavity so that the targeted cracks can be filled with the PU resin. Once the resin has set and cured, the water path is cut and water leak stops. It is recommended that the first step towards sealing a leak is to start off with PU injection prior to trying other methods of repair. It has been proven effective on many types of substrates such as blockwall, brickwall and concrete structures.

Water migration is, however possible after injection since it is a targeted repair. Therefore, it is important to understand this before a no confidence vote is taken. Water migration is a problem associated with concrete quality and it is often overlooked due to warranty elements of the waterproofing work given by waterproofing contractor.

b) Penetrating and Filling By Gravity Pressure Using Silane-Siloxane Solution ***(BS EN 1504 part 2 and 9)***

This method can only work when there is very low or no hydrostatic pressure. Provide temporary containment assemblies on top of leaking area (extent of area to be determine on site) and flood Silane-Siloxane solution to a height of 25mm. Leave solution standing for 3 to 7 days.

The solution penetrates into porous substrate, cavities and then reacts to produce a lining that is water repelling.

10.3 Leaks at Structural Cracks

Step 1: Pressure Grouting (Injection) Method Using Structural Polyurethane Resin to fill cracks. ***(BS EN 1504 part 5 and 9)***

Typical Properties

- Adhesive Strength (wet surface): 2.1MPa
- Compressive Strength: 35MPa to 80MPa
- Shear force (glued to wet surface with 0.1 to 0.5 MPa tension): Cohesion 1.9 MPa Shear angle 65 degrees
- Shore Hardness: D78 plus/minus 5
- Application Method: Refer above 10.2a paragraph 7&8

Photo 12:
Pressure Grouting Polyurethane Grout

Step 2: Carbon Fibre Reinforcement Composites Systems To strengthen Structure Design and Application:

- A qualified Structural Engineer would be required to design the system.
- Following that and approved (by manufacturer) and experience applicator is required to carry out job.

Typical Properties

Carbon Fibre Plates:

- E- modulus: 165,000N/mm2
- Tensile strength: 2800N/mm2
- Average measured failure tensile strength: 3,050N/mm2
- Strain at failure: >1.7%

Photo 13:
Carbon Fibre Plates for Strengthening of Concrete Slab

Carbon Fibre Fabrics:

- Tensile strength of fabrics: 3,500N/mm2
- Tensile modulus of fibres: 230,000N/mm2

Photo 14:
Carbon Fibre Fabrics for Strengthening of Concrete Beams

Epoxy Adhesives:

- Compressive strength: 80N/mm2
- Adhesive strength: 3N/mm2(concrete failure)
- E- modulas: 12,800N/mm2

10.4 Movement Joints leading to Leaks *(BS EN 1504 Part 5 and 9)*

a) Expansion Joints *(BS EN 1504 Part 5 and 9)*

Leaks at expansion joints are mainly because the sealants de-bond from the concrete. A Hypalon sheet could be epoxy adhered on ends of the sheet onto the concrete substrate to mitigate the leak and also allow for movement.

Typical Properties:

Hypalon Sheet

- Size: 1mm thick x 100mm wide x 25m long
- Tensile strength: >6N/mm2
- Elongation at break: 400%

Photo 15:
Hypalon Sheet for Bandaging Joints

Epoxy Adhesive

- Component: 2; Hardener and Resin
- Bond strength: > 2N/mm2 (concrete failure)
- Compressive strength: 50N/mm2

b) Construction Joints *(BS EN 1504 Part 5 and 9)*

Leaks at Construction Joints are like non-structural cracks. The remedial treatment would be the same as in item 10.2a.

10.5 Leaks from Parapet wall traveling into Slab.

It also very common for leaks to come from the plaster cracks of the parapet wall. The possible solution is to fill the cracks with an elastomeric sealant and repaint with and elastomeric coating.

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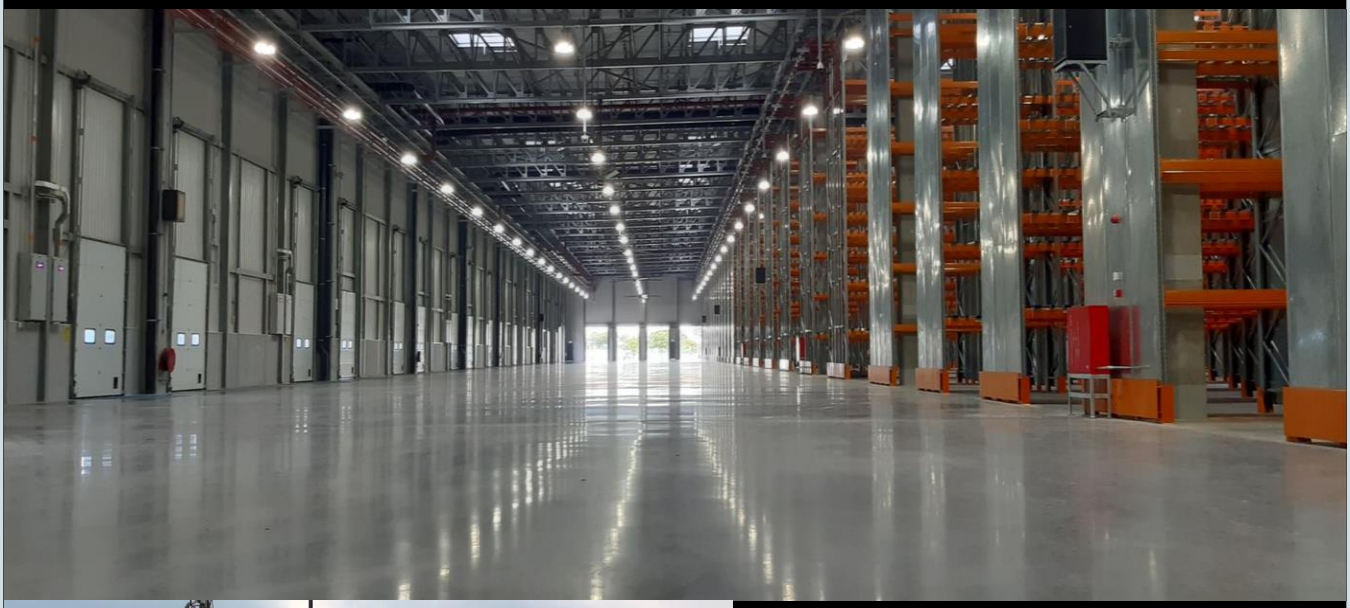

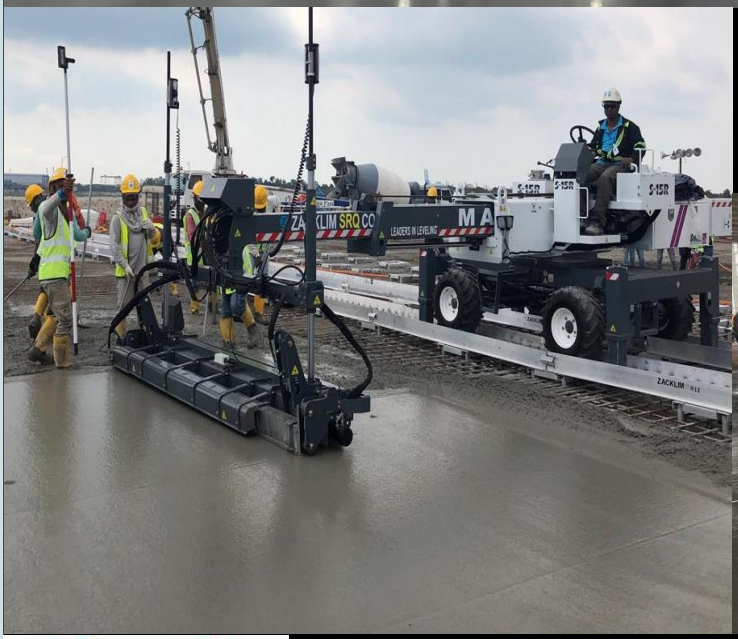

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