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Experimental Study on Common Non-Destructive Tests for Moisture Measurement in Reinforced Concrete Residential Building

9 Dec 2021

Ir Kenneth PAK

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The Non-destructive Test (NDT) equipment adopted in the experiment

- Microwave Moisture Meter (MMM)
- Surface Moisture Meter (SMM)
- Multi-channel Ultrasonic Tomography (MCUT)
- Ground Penetrating Radar (GPR)
- Infrared Thermography (IR)

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Aims of Project:

- Collect supporting information for drafting the Technical manual on MMM proposed by HKCI.
- Study the relationship between surface moisture and MMM result.
- Suggestion on the use of IR for water seepage detection.
- Review the time required for carry out a water ponding test.
- Review the use of ultrasonic tomography for monitoring moisture in concrete.

An abandoned building in To Kwa Wan District

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The Key Team Member:

Name	Role	Background
Ir Kenneth PAK	Principal Investigator	<ul style="list-style-type: none"> HKCI: Fellow Member CN/IVE/TY: Senior Lecturer HKIE: Corporate Member (Structural Div), Committee Member (Materials Div)
Mr Tommy CHAN	Investigator	<ul style="list-style-type: none"> Fugro Technical Services Limited: Manager HKIE: AMC Chairman (session 2018-2020) HKTIC: Certified Testing Professional IVE/TY: Part Time Lecturer
Mr Ringo LAM	Investigator	<ul style="list-style-type: none"> Qualitech Testing & Consultancy Limited : Deputy General Manager HKCI : Member
Cr Kenneth LEE	Investigator	<ul style="list-style-type: none"> Castco Testing Centre Ltd: Engineer HKIE: Corporate Member (Materials Div) IVE/TY: Part Time Lecturer
Mr LEE Kai Man	Investigator	<ul style="list-style-type: none"> CN/IVE/TY: Lecturer RMC, MHKICM, MCIQB, AS(RGBC)
Mr LOO Wai Chung	Investigator	<ul style="list-style-type: none"> CN/IVE/TY: Lecturer
Ir Adrian MA	Investigator	<ul style="list-style-type: none"> Castco Testing Centre Ltd: Engineer IVE/TY: Part Time Lecturer
Mr Kris CHEUNG	Technician	<ul style="list-style-type: none"> CN/IVE/TY: Senior Technician
Mr Dylan WONG	Technician	<ul style="list-style-type: none"> CN/IVE/TY: Technician

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The Advisory Panel

Name	Role	Background
Mr Wayne CHAN	Advisor	<ul style="list-style-type: none"> Savills Project Consultancy Limited: Director and Head Authorized Person Registered Inspector HKIA: Member APRC/ CRC/ MWCRC: Committee Member Appeal Tribunal (Buildings): Member HKU: Adjunct Assistant Professor VBAS Assessor (List 1) BEAM Pro
Sr David W.W. Chan	Advisor	<ul style="list-style-type: none"> HKIS/ RICS : Fellow Member (building surveying) HKIS : Chairman [1990-91] of Building Surveying Division HKIS BSD : Chairman (2015 – 2021) of List of Experts for Water Seepage Investigation Committee Building Authority : Authorized Person/ Registered Inspector HKPU : External Examiner [1991-96] of BSC (Hons) in Building Surveying
Ir William TF CHAN	Advisor	<ul style="list-style-type: none"> HKIE: Corporate Member (Materials Div)
Sr Samson CHAN	Advisor	<ul style="list-style-type: none"> HKIS: Member (Building Surveying) RICS: MEMBER (BUILDING SURVEYING) REGISTERED INSPECTOR BD: Authorized Person (Surveyor)
Ir Stanley CHAN	Advisor	<ul style="list-style-type: none"> HKIE: Corporate Member (Materials Div) ACML: Chairman

Name	Role	Background
Mr Ray CHANG	Advisor	<ul style="list-style-type: none"> HK PolyU: Research Assistance IVE/TY: Part Time Lecturer
Mr Allan KO	Advisor	<ul style="list-style-type: none"> ICWCI (HK) Member (Secretary) CICES Member CIPHE Member
Ir CS LAM	Advisor	<ul style="list-style-type: none"> HKIE: Corporate Member (Materials Div)
Prof. Joseph MAK	Advisor	<ul style="list-style-type: none"> HKIE: Chairman, HKIE Materials Division Ex Chief Structural Engineer, HKHA
Sr TANG Chi Wang	Advisor	<ul style="list-style-type: none"> ADWISE Building Consultancy Limited: Executive Director HKIS: Fellow HKIS: BSD Vice-Chairman VTC: Member of Building, Civil Engineering and Built Environment Training Board PolyU: Member of Advisory Committee of Dept of Civil and Environmental Engineering
Ir Edmond WONG	Advisor	<ul style="list-style-type: none"> CN/IVE/TY: Head of Department HKIE: Corporate Member (Structural Div)
Ir Samson WONG	Advisor	<ul style="list-style-type: none"> Ex Senior Accreditation Officer (HKAS) Ex Senior Structural Engineer (Housing Department) HKIE: Corporate Member (Structural Div, Materials Div, Environmental Div) HKCI: Fellow Member

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Experiments Details

- No. of water ponding test carried out = 5
- Detail of water ponding test:

Location of test	Depth of water (mm)	Duration of test	Observation	Remarks
Kitchen	150	72 hours	Water seepage occur at 10mins after water applied. Water dripping observed.	There is a severe crack along the floor slab
Bedroom	150	72 hours	No water seepage detected.	
Living room	150	72 hours	Water seepage occur in the adjacent rooms. The ceiling underneath maintain in dry condition.	
Roof (1)	150	72 hours	No water seepage detected.	
Roof (2)	300	30 hours	No water seepage detected.	

Kitchen x 1, Toilet x 1, bedroom x 1, living room x 1, roof x 2

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Exp 1: Water Ponding Test at 1F2C

- Determine the location of rebar in concrete slab by GRP.
- Make measurement from the bottom side of the slab as datum, including IR, MMM, SMM, MCUT.
- Take measurement at 2 types of location
 - at the rebar
 - centre point between rebars
- Pond water (with colour dye) on the surface of slab, depth of water = 150mm
- Make measurement from the bottom side of slab at 1 hour interval for 3 days.

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Exp 1: Water Ponding Test at 1F2C

Water ponding of 150mm

Observed water seepage from the bottom side of slab after 10 minutes of water ponding

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Exp 1: Water Ponding Test at 1F2C

Open up the floor tile after 3-days water ponding

Identified a crack along the slab

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Exp 1: Water Ponding Test at 1F2C (Measured at location w/o rebar)

	TL0	TL1	TL2	TL3	TL4	TL5	TL6	TL7	TL8
Average	535	1552	2702	2038	2977	3089	3097	2573	2592
Max	814	3434	3665	3650	3654	3782	3834	3795	3606
Min	469	504	1020	602	654	1208	982	812	1093
Median	525	1496	2894	1997	3353	3284	3593	2774	2862
SD	46.86	777.74	728.58	795.94	806.76	798.14	761.79	663.30	702.97

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Exp 1: Distribution of Moisture Index of Water Ponding Test at 1F2C

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Exp 1: Water Ponding Test at 1F2C (Rebar+Concrete VS Concrete only)

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Exp 3: Point Source at Roof Floor




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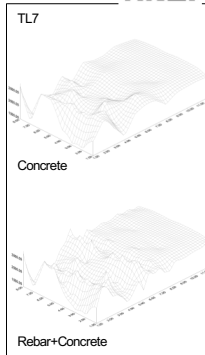
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Effectiveness of the MMM in Moisture Measurement

- The MMM is **sensitive to moisture and rebar** in concrete.
- Proven that rebar in concrete **interferes** the reading of MMM. The difference in Moisture Index may reach **23%**.
- Penetration strength of MMM probe varies against the moisture content of concrete. In general, penetration strength reduce with increase of moisture content.
- Subject to the proper use of MMM, the technology is **effective** for moisture detection in concrete.

TL7



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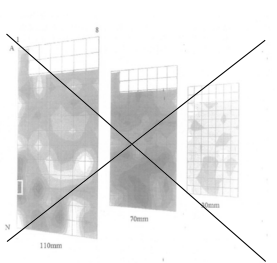
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Recommendation on the use of MMM

- Locate layers of rebar and voids in concrete by **GPR**.
- For consistent measurement, **take reading at the mid-point between rebars**.
- Moisture index contours prepared by different MMM probes **shall not over-lay** for tracing the "source of moisture".
- Shall carry out **further study** on the interference from rebar on different probe of the MMM.

J.D. First Microwave tomography for buildings outline with 30m, 70mm and 110mm depth probe

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Recommendation on the use of MMM

- Shall carry out **further study to bench mark the moisture index and moisture content for local concrete**.
- The bundled software for plotting the moisture contour do not able to cater "omitted" data in grid measurement. Suggest to **use alternative software for plotting contour** when there are obstructions in data collection resulting "omitted" data in grid measurement.
- To adopt **time lapse measurement** to verify the cause of water seepage.



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	TL0	TL1	TL2	TL3	TL4	TL5	TL6	TL7	TL8
Average	534	1636	2760	2189	2921	3094	3099	2520	2694
Max	814	3595	3669	3600	3657	3782	3834	3795	3710
Min	469	492	828	602	654	1121	875	812	957
Median	524	1555	2824	2212	3354	3147	3620	2717	2881
SD	46.04	840.92	747.34	790.79	876.52	786.94	783.14	661.04	681.55

	TL0	TL1	TL2	TL3	TL4	TL5	TL6	TL7	TL8
Average	535	1552	2702	2038	2977	3089	3097	2573	2592
Max	814	3434	3665	3600	3654	3782	3834	3795	3696
Min	469	504	1020	602	654	1108	862	812	1093
Median	525	1496	2884	1997	3353	3284	3593	2774	2862
SD	46.86	777.74	728.58	795.94	806.76	798.14	763.79	663.30	702.97

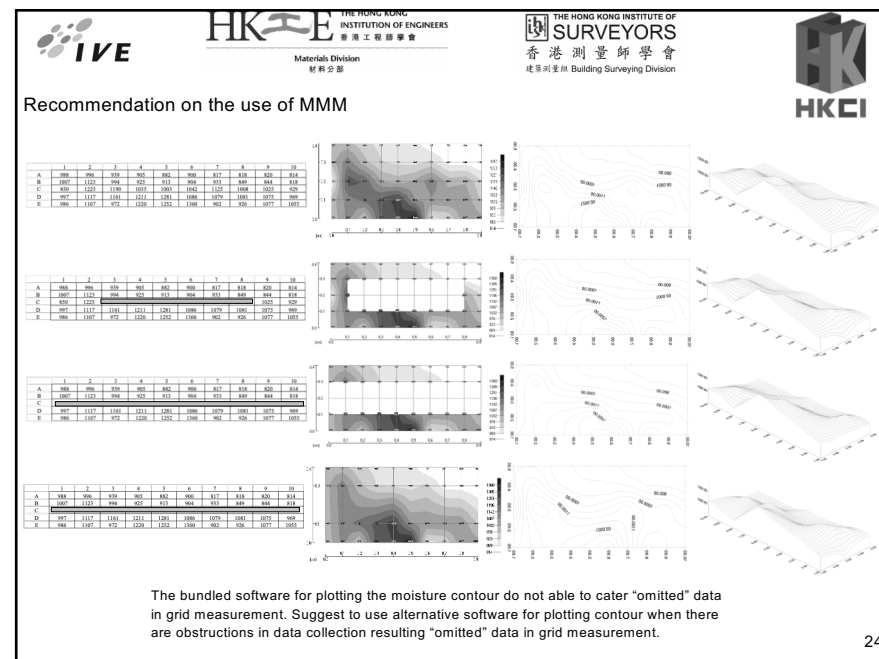
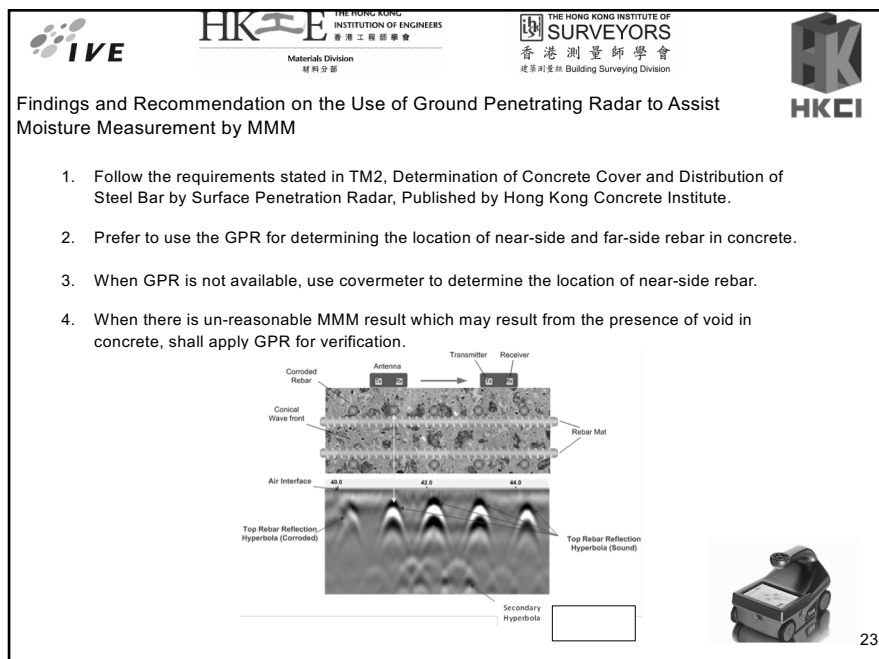
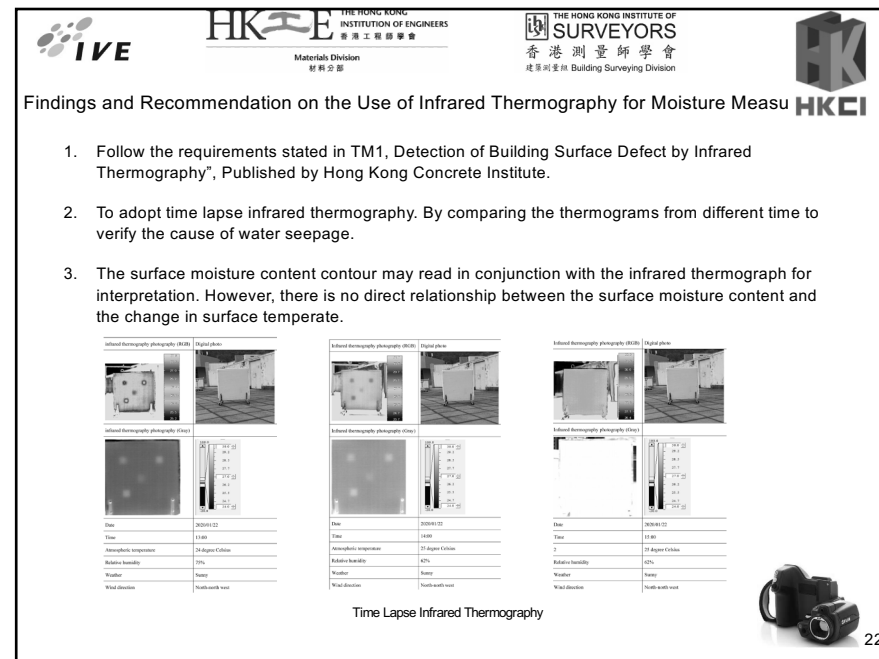
Concrete+Rebar VS Concrete Only									
	TL0	TL1	TL2	TL3	TL4	TL5	TL6	TL7	TL8
Average	0.06%	5.13%	2.10%	6.89%	1.94%	0.18%	0.06%	2.09%	3.79%
Max	0.00%	4.48%	0.11%	0.00%	0.08%	0.00%	0.00%	0.00%	3.04%
Min	0.00%	2.44%	23.19%	0.00%	0.00%	7.76%	12.23%	0.00%	14.21%
Median	0.29%	3.79%	1.03%	9.72%	0.07%	1.87%	0.75%	2.10%	0.64%
SD	1.80%	7.51%	2.51%	0.65%	7.96%	1.68%	2.73%	0.34%	3.14%

Interfered by rebar

Without Interference

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Thanks to the support from the following organizations: (in alphabetical order)

1. Brilliant Engineering Equipment Co., Ltd.
2. Castco Testing Centre Ltd.
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4. Qualitech Testing & Consultancy Limited
5. Urban Renewal Authority
6. Student Helpers from IVE/TY



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