Key Points

Course Description – Supplement to National Environmental Health Association National Radon Proficiency Program

Prerequisites:
Completion of National Measurement and Mitigation Courses
Completion of Guam Specific Radon Measurement Course

Program
All course materials and online coursework available at www.certi.us
Video and audio played from computer with slides.

Guam Certification:
Arrange for the Guam Specific Mitigation Exam (which includes the Measurement Portion) through Guam Community College
(671) 735-5516

Overview of Challenges on Guam

• Foundations
  • Slab-on-grade, with thick layer of crushed and compacted limestone beneath slab
  • No crawlspaces or drainage systems – no attics for interior fan location

• Climate
  • Tropical – Hot and Humid
  • High rainfall – potential roof leaks, rain caps

• Earthquakes
  • Ferro concrete with LOTS of re-bar
  • Thickened slabs at perimeter walls can be large expansion joints

• Typhoons
  • Wind speeds can exceed 200 miles per hour with flying debris
  • Strong and more frequent supports needed, especially for exterior mounted systems

• Corrosion
  • Salt air can corrode exposed metal components.
  • Plastic or stainless steel construction needed
Slab-on-Grade Foundations

- Homes constructed on compacted limestone
- Tight soils

Key Points

- Mostly slab-on-grade constructed on thick layer of limestone
- Heavy reinforcement due to earthquake codes

Compacted Limestone

- Radon follows discrete pathways
  - Utility trenches
  - Between compacted fill and foundation wall
  - Through cracks openings in limestone layer due to movement

*ASD systems that do not impact pathway or underlying native soils will likely not work.*

High soil pressures force radon up into buildings through openings that may be difficult to directly impact with a suction pit.
ASD Suction Pit Approach: Interior Pits

- Objective:
  - Withdraw radon from below the compacted limestone layer.

- Approaches
  - Large, deep pit-interior to building
  - Through foundation wall below limestone
  - Under footing into native soils

*Typical - though slab suction pits as used in mainland are inadequate!*

Key Points

**Interior Pits**

<table>
<thead>
<tr>
<th>A suction pit that does not penetrate the limestone will easily be defeated.</th>
<th>The pit has to extend to the native soil.</th>
<th>Suction pipe connected to pit that went to bottom of footing</th>
</tr>
</thead>
</table>

**Pros:**
- Very effective
- Can treat multiple rooms. The system in the photo above was able to treat several classrooms even though 3 foot deep footings separated them

**Cons:**
- Very labor intensive - saw cutting concrete and lots of dust and dirt inside home
  - One can reduce dust with the application of water as well as locate the suction hose of a shop vacuum near saw (with shop vacuum located outdoors) and exhaust outdoors.
  - Can intrude on interior useable space
ASD Suction Pit Approach: Single Exterior Suction Point

Pros:
- All components exterior to home - reducing impact on homeowners during installation.
- No loss of interior space
- Less expensive than large interior pits

Cons:
- May not result in full reduction
  - Increase number of suction pits
  - Combine with fresh air/mechanical system approach (discussed later)

Key Points

Sub-Footing Single Point

Exterior single point pit below footing. Contacts native soils

Hand dig down to footing
Install collection box. Connect to vent riser. Refill and compact

Side Core

If aggregate or gap is beneath slab, tie into it

Core through foundation wall. Avoid rebar and coat nicked rebar
System completely on outside

Can have two suction points on each side of interior footing with common fan
Consider interior pit with exterior connection

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**ASD Diagnostics**

- Find the Entry Point
  - If there is radon in the building, it is coming in somewhere
- Long drill bits necessary to penetrate through compacted limestone layer.

**Key Points**

- ASD Diagnostics can be deceptive if not done properly.
- Use long bits to access below compacted limestone.

**Approach**

1. Locate hollow areas with mallet and preferred installation location
2. Drill shallow vacuum holes and pilot holes
3. Determine if there is communication
   - Yes -- There is aggregate under slab or an air gap. Shallow pit will likely work
   - No -- Go deeper
4. Drill deeper and into native soil – may require 36-inch bits
5. Repeat diagnostics to determine communication
   - Yes -- Need deep pit
   - No -- Find another location and start again

**Equipment**

- Smoke bottles may be useful, but micromanometer is better
  - During calm weather or falling tide, smoke will go down pilot hole on its own
  - Micromanometers can show relative change with vacuum cleaner ON/OFF
- Use a large shop vac (3 horsepower minimum)
Key Points

- Radon entry into Guam buildings is due to soil pressures
- High volumes of radon laden soil gas from underlying limestone formations
- Design for high volume moderate vacuum
  - Normal radon fans as used in U.S. mainland work well
  - One may think that high vacuum low volume fans are best due to tight, compacted limestone fill, but to achieve reductions one needs to draw from below compacted layer.
- Heat
  - High heat and direct sunlight (as well as power surges) can cause capacitor failure
    - Specify fans with heavier duty capacitors
    - Enclose in white cover
- Water / Rainfall
  - Install water separator on discharge
  - Rain cap on termination
  - Insure handi-box is tight (apply caulk)
  - Run electrical in water tight conduit
Key Points

- High winds are very common on Guam –
  - A wind speed of 236 miles per hour was recorded during Typhoon Paka just before the instrument was damaged.
  - Use channel and unistrut to secure pipe outside
  - If fan is roof mounted-use stainless guy wires

- Corrosive atmosphere
  - Use stainless or galvanized metal parts
  - Paint tops of screws and concrete anchors

- Earthquakes
  - Insure there are flexible couplings above and below fan

- Sunlight
  - Utilize UV resistant pipe when mounted outdoors
  - Schedule 40 plastic pipe - Drain waste and Vent (DWV) or pressure rated if DWV unavailable.
  - Sand and paint exposed pipe
ASD Approaches

- External systems work if care is taken to select suction point
- Intersect utility trenches
- Construct to withstand high winds
- Standard radon fans work well
- Operate systems continuously

Key Points

ASD Tips:
- Check terrain to determine if house has been built up - pick a location where the dig is not so deep
- Utility trenches:
  - Typically 2 feet wide, at perimeter and less compacted than interior portion of slab.
  - Connecting suction point to utility trenches can extend pressure field significantly
  - Be careful when digging
- Side wall penetrations have been very successful
- Fans typically mounted in back of home for aesthetic reasons
- Often tie in just below slab, especially if you can connect to utility trenches
- Older homes, typically have more loose soils beneath them
- If pipe comes out of ground - protect bottom of pipe with a little concrete to avoid pipe being cut from bush cutters
- Fan shrouds improve appearance and helps protect fan from sunlight and rain.
- Durability has been good, provided system is well secured with heavy duty brackets
  - Unistrut with galvanized channel and stainless steel clamps
- Use fully paintable components

Performance Indicators
- U-tubes dry up if installed outside – inspect every 6 months
- Electric style indicators work very well
  - If installed outdoors be sure to use weatherproof enclosures to reduce corrosion

Labels
- Label systems to identify them as radon systems and also who to call for service
- Regular vinyl is used but can fade within 3 years
- Consider applying new labels as part of periodic retesting program

Other Benefits
- Anecdotal indication of reducing soil moisture into home which can improve indoor air quality

Common Failure Mechanisms
- Fans not running continuously which can cause fan bearings to seize.
  - Can happen if fan is OFF for even just a few months
  - Breakers tripping without indication to homeowner.
  - Homeowners shutting off during day to save electricity.
- Advise homeowner to run fan constantly

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Guam Challenges and Interior Suction Pits

Geoff Burke
Burke Engineering
- Mitigator on Guam since early 1990s
- Things are different from the Mainland U.S. on Guam
- Interior suction pits

If you have not tested your house for radon – do so!

Section 9

Key Points

Driving Forces
- Things are quite different on Guam - Significant driving forces on Guam
- In mainland U.S. thermal differences cause radon to enter, but in Guam soil pressures can play a major role
- Dry season versus wet season is the major seasonal difference as compared to winter/summer
- Rain moving down to the water table causes radon laden soil gas to be pushed up into home
- One out of three houses in Guam elevated - compared to one in 15 in mainland U.S.

Construction
- Compacted base course under large buildings (as much as 3 feet)
- At least 12 inches under homes or heavily compacted native soils
  - Communication can be limited if clays re-used and compacted
- Source is native soil and not building materials, even if limestone used in concrete

Suction Pits
- Prefers to install large pit centrally located in home - about 1 cubic yard pit
- Extend to depth below bottom of interior footers
- Manual installation and lots of dust created within house - use plastic as well as a blower to pull dirty air from within home
- Do not fill pit with large rock
- Reconnect rebar (leave 3-inches of old rebar to re tie to) - re-pour concrete slab - reapply tile if applicable.

Roof Mounted Fan
- If interior pit used, the vent piping will go through roof with fan located on roof (no attics in Guam)
- 3/8-inch stainless steel cable (SS 308 or 314) with turnbuckles to snug up fan.
- Typical U.S. radon fans work well on Guam - exterior parts should be stainless or plastic
- Roof Penetration:
  - Concrete bonding agent
  - Two part polyurethane foam around the pipe
  - Concrete poured around pipe on roof to build up around pipe to cause rain to drain away
- Rain caps on discharge have not diminished capacity
- Schedule 40 PVC is more than adequate

UV Protection
- Ideally apply an enamel or an epoxy paint to protect - sand and paint
- Most current PVC has a good UV protection factor even without paint.

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Fresh Air Make-Up to A/C Systems

Key Points

- Fresh air is often designed into air conditioning systems.
- Retards radon entry by pressurizing interior as well as diluting the radon.
- Also reduces interior moisture that can lead to mold by insuring that air that enters the building first passes over an A/C coil before entering the building. Reduces tramp air entry.

1. Verify if dampers are open – if not, open them.
2. Check condition of ductwork if air handler is exterior, pad or roof mounted.
3. If no dampers exist, determine if fresh outdoor air can be added through consultation with a mechanical engineer -- use if a qualified HVAC contractor.

The graph on the left shows hourly radon measurements in a home in which the outdoor damper was closed and then opened.

The impact on indoor radon levels can be dramatic through a simple action such as opening a damper that may have been closed during a typhoon.

Split A/C units were added to several Guam classrooms with a significant reduction in rooms that had elevated radon levels.
Adding Fresh Air To A/C Systems

- Improves indoor air quality
- Must be properly designed
  - Mechanical engineer
  - Verify capacity of A/C unit
  - Allow for condensate drainage

Key Points

- Adding fresh air to an A/C unit (or designing this in for new buildings) can have several other indoor air quality benefits
  - Can help dehumidify air that would have otherwise entered the building through doors and leaky windows.
  - Can significantly reduce radon
    - Due to tightness of concrete constructed buildings in Guam, a small amount of air supply can have a huge impact.
- Consult with a Mechanical Engineer
  - Insure capacity of unit to handle additional load.
  - Insure proper moisture handling
- Approach
  - Use a licensed mechanical contractor
  - Verify air flows
  - Label dampers and mark damper positions to avoid inadvertent closing of dampers, except during typhoons

Hole cut into return side of air handler and damper installed

Damper adjusted to insure maximum air flow specified by mechanical engineer is not exceeded

Damper position marked and a stainless ID tag riveted to damper assembly advising to leave damper open
**Key Points**

**Sizing Diagnostics**

- Use blower door or make a pressure door (plastic in door with variable speed blower and air flow measurement devices)
- Use micromanometer to measure differential pressure (dp) from interior to sub-grade
- Turn on all exhaust fans to determine maximum pressure differentials across slab that will have to be overcome by system.
- Vary air flow and make measurements. Plot data as shown below
- Drawing a straight line through data points is reasonable for low pressure differentials.
- Use number to determine air flow needed based upon experimental data.
- Determine if air conditioning system is capable of handling this amount of fresh air make-up

**Pressure door**

*Plastic taped in door with variable speed fan and air flow measurement device. Plot data*

*Determine fresh air needed (CFM) to achieve pressurization. Verify A/C has capacity*
Air Conditioning Systems in Guam

Conrado G. Vales, P.E.
EMC² Mechanical, Inc.
Tamuning, Guam

“"It is a must to have outside air.""

Closing fresh air make-up does not save as much energy as people think and can cause indoor air quality problems.

Building codes on Guam require fresh air for “habitable spaces”.

Key Points

History

• Buildings previously used natural ventilation with open louvers. There has been a transition to air conditioning systems with clear plastic covering louvers, which reduces ventilation.

• Indoor air quality goes down unless recommended outside air is added per ASHRAE 62.1.

• Air conditioning systems should be designed to bring in outside air.

• The current Uniform Building Code in Guam requires “any habitable space to be provided with outside air.”

Types of Air Conditioning Systems:

• Window/through the wall units

• Mini-splits:
  • Basically a fan coil mounted on a wall with refrigerant piping to the condensing unit
  • Usually no provision for outside air

• Ducted splits:
  • Similar to a mini-split but distributes air via ductwork that allows for fresh outside air
  • Sized to allow for fresh air introduction.

• Distributed Systems:
  • Large central units with ducting to distribute air
  • Outside air always provided in accordance with ASHRAE 62.1
  • Dehumidification coil precedes primary cooling coils to aid in reduction of moisture

What happens when a person shuts off the outside air make-up:

• Indoor air quality goes down - even if you shut off the O.A. make-up, outdoor air still infiltrates building
  • Air enters via doors and windows and can cause a mold problem
  • Energy savings is not what people think

• Maintenance of A/C
  • Filters not being cleaned (indicated by dirt around diffusers) - filters should be changed monthly

• Advanced Controls
  • Carbon dioxide sensors can be installed to bring in outside air when people are present and shut off when building is not occupied

• Adding fresh air to existing air conditioning
  • Need to verify A/C system has capacity
  • Requires verification of system capacity and means for draining condensate away
  • “It is a must to have outside air”
Key Points

• Some buildings can be difficult to mitigate with a single approach, especially if the pathway by which radon is entering is difficult to apply an ASD system to.

• The graph on the slide provides the results of an incremental approach that was taken on a difficult home on Guam
  
  • The installation of a single point suction system essentially reduced the radon in half, however the result was well above 4.0 pCi/L.
  
  • The addition of fresh air make-up working in combination with the ASD system was able to significantly reduce the levels further.
    
    • Alternatively, an interior pit could have been installed to make the ASD system operate more effectively. The owner preferred to avoid such an intrusive approach and wanted to improve the indoor air quality of the structure, which is why the approach of adding fresh air make-up was taken.

Radon Decay Product Reduction

• In the same house, radon decay products were simultaneously measured

• Although the combination of an ASD system and the fresh air make-up brought radon levels to essentially 4.0 pCi/L, the air movement of the air conditioner in conjunction with cleaner outdoor air in Guam reduced the actual radon decay products to well below 4.0 pCi/L

Air circulation caused by A/C unit reduces radon decay products so that the combination of ASD, fresh air, and air circulation reduces radon decay product exposure to well below guidance.
HVAC Approaches

- Good technique to follow ASD
- Good for addressing other IAQ concerns
- Requires proper maintenance
- Consider impact of Radon decay products

Key Points

Benefits of HVAC Approaches:
- Good add-on to Active Soil Depressurization
- Improves Indoor Air Quality as well

Challenges of HVAC approaches:
- HVAC can be vulnerable to occupant shutting of fresh air make-up
- Fewer maintenance problems with ASD
- Shell pressurization can be impaired:
  - When filters are not routinely changed
  - Inlets can become clogged-need to inspect and clean
  - Maintenance contractors may not be aware of parameters of HVAC air flows needed for radon control
    - Add labels on equipment advising of need to maintain fresh air

Impact on Radon Decay Products:
- Radon Decay Products are reduced with high circulation when A/C System is operated
- High efficiency filters can further reduce RDPs as well as particulates
- If lower levels desired, consider looking at RDPs
  - Measure Radon and Radon decay products simultaneously
- Either A/C on with low RDPs or open windows which will reduce radon
- If occupant turns off A/C during work day, RDP testing might not indicate actual lower levels if testing occurs during periods A/C is shut off
  - Passive Measurement Devices – test with A/C on continuously
  - Hourly measurements – have occupant note times when A/C is On or Off. Allows correlation with lower radon decay product levels

HVAC approaches help further reduce radon levels after active soil depressurization and has effect of further lowering exposure via radon decay product reduction
Key Points

Heat and Sunlight
• Hydrate yourself the evening before project - have water on jobsite
• Use sun block - use hat – hard hat - sunglasses
• Long sleeve white shirt and light clothing

Personal Protective Equipment (PPE) - Do not share personal protective equipment with others.
• Eye protection – safety glasses and or goggles
• Gloves – especially when digging out pits and working with rebar
• Hearing protection
  • Disposable foam types are comfortable - Ear muffs provide better protection - not as convenient
  • May need both foam plugs and Ear muffs (shop vacuum and hammer drill at same time).
• Respiratory Protection
  • Sanding and grinding - Disposable – nuisance mask
    • Not a fit tested mask where full respiratory protection would be needed
• Foot Protection
  • Safety shoes - no zorries or flip flops!

Power Tools
• Inspect tools and cords prior to operation - sharp bits - guards in place
• Be sure surroundings are clear when using hammer drills and core rigs.
• Be able to get away from drill when it binds up
• Electrical Shock
  • Connect cords via Ground Fault Circuit Interrupter
  • Disable circuit – lock out – tape over breaker while working on circuit

Insects
• Wasps can be troublesome – spray
• Mosquitoes yes, but not malaria carriers

Digging
• If digging deep, use shoring - rope off area, especially if left over night

Ladders
• Secure top and bottom of ladder
  • Extend spike into soil or rubber feet for solid surfaces - Tie bottom so it does not kick back
• Barricade around ladder so it is not disturbed and protects individuals below from dropped tools
• Work in front of you rather than extending far off to one side. Move ladder if necessary
• Harness at high heights
Key Points

Radon Resistant New Construction:
• Similar to the U.S. mainland, the installation of radon control systems makes strong economic sense
• Most applicable in the areas of the Island that are being developed on limestone geologies.
• The techniques that would be used on Guam would be identical to those described in CERTI’s National Mitigation Course, with an emphasis on those techniques that treat slab-on-grade structures.

Radon in Water
• Tests conducted by Guam EPA do not indicate a concern of radon entry via water supplies.

Emanation
• There is no information to date to indicate a concern with building materials having sufficiently high radium content to present an emanation concern.
• There is no information to suggest that elevated levels of radon are due to atmospheric bomb tests that occurred in the pacific in the previous century, or any other human activities on the island.
Radon Resistant Construction Experience on Guam

Key Points

• RRNC is a requirement on Guam for all new buildings on military installations
• Passive systems operate differently on Guam, but they still function
  • No thermal stack effect to create draw on passive vent pipes
  • Connection to sub-grade allows soil pressure to force radon laden soil gas up through stack
• Sub-grade
  • Washed gravel as is common in the mainland U.S., but not readily available on Guam
  • Washed crushed coral (fines removed) is available and provides a permeable layer under slab.
  • Perforate pipe under slab located within the aggregate layer
    • For single family homes a single 20 foot length of perforated pipe
    • Pipe through footer of intermediate bearing walls to insure communication on either side of potential barrier
      • Connect to permeable layer or loop system after footer poured
    • Typically a rigid schedule 40 pipe is used and ½ inch diameter holes are drilled in.
      • Paul recommends 4 holes, with 1 oriented downward so water can drain out
    • Loop of perforated pipe when native soils are used
  • Common to have 6-mil vapor barrier as a vapor barrier
    • Seams are not typically caulked and sealed - overlap and tape edges to hold in place - weight of slab holds seam together well.
    • Plumbing and conduit penetrations sealed with polyurethane caulk or foam
    • Slab’s floor to wall joint is typically a cold joint and joints are not caulked
• Vent pipe
  • 4-inch minimum - routed up interior, such as within a plumbing chase
• Fan
  • Test building after construction - if necessary, install fan on roof
  • No attics on Guam – install fan outdoors – essentially the roof for future RRNC fans.
  • Route an empty conduit to potential fan location
• Limestone as a building material is not importing a source to a home.
  • Limestone from quarry can be used for construction
• Designing for fresh air make-up can reduce indoor radon as well as augment RRNC systems

How well do passive system work?

“So far passive systems installed in southern military installations have not required activation.”
Key Points

To conduct mitigation work on Guam:

- Homeowners are able to conduct work on their own homes

Professionals:

- Business license from the Department of Revenue and Taxation
- Talk to your insurance company
- If you have employees, there is a requirement under OSHA that employees be trained for proper safety practices.
- Insure you have proper safety equipment
- License from Guam Contractor’s Licensing Board
- No special requirements (yet) for offering radon services beyond that which is required as a contractor
- Electrical (either in-house or via subcontractor)
- Normal business requirements

Materials & Tools:

- Specialty equipment ordered from mainland U.S.
- Most piping components and brackets available on Guam
- Requires tools and bits capable of working with concrete and rebar

Marketing:

- Public service programs
- Do year round, but especially during national radon month
- Need to be honest and not market fear
- Provide good information

- Advertising
  - Word of mouth is very powerful on a small island
    - Good work travels, bad work travels faster.
  - Cost is an issue since radon mitigation may consume one or two paychecks for a homeowner
  - Help friends install systems to begin word-of-mouth marketing and to gain experience
Case Study – Interior Pit Exterior System

Key Points

One story, slab-on-grade, steel reinforced concrete

- Previous radon measurements in excess of 30 pCi/L
- Diagnostics revealed thickened slab at perimeter, shallow footings, compacted limestone under slab
- Approach: Interior pit with external system

Comments:

- Deep pit able to draw from beneath grade beams
- Communication throughout sub-grade
- Good reductions, especially in terms of radon decay products
- Installation accomplished in 2.5 days with two people
- Fan: Fantech HP-220 with MI-220 indicator
**Case Study – Exterior Wall Cores**

**Exterior System**

- Two story, slab-on-grade
- Radon measurements:
  - Above 50 in lower level
  - 18 pCi/L on second floor
- Two single suction points through exterior wall connected to common fan
- Vent system on exterior

**Key Points**

Two story, with lower level being slab-on-grade, steel reinforced concrete.

- Previous radon measurements in excess of 50 pCi/L on first floor and 18 pCi/L on second floor
- Loose fill under slab
- Approach: Two single suction points through exterior wall connected to common fan.

**Comments**

- Significant reductions in both radon and radon decay products
- No impact from rain after installation
- KTA-150 fan utilized
- Work accomplished in 1.5 days
- All components exterior to building
Key Points
To conduct the online coursework, do the following:

• Go to [www.certi.us](http://www.certi.us)
• Click on “Radon Training”
• Click on “CERTI University – Conduct Coursework”
• Log in with your Username and Password provided when you purchased the course
• Click on the course title
• Review Case Studies and Resource Materials
• Complete Quizzes
• Download your Course Certificate

Certification Exam:
• If you are planning to become certified either as both a Measurement and Mitigation Provider or just a Mitigation Provider – Contact Guam Community College to schedule the Certification Exam.

**************************************************
Special thanks to:
Guam EPA for research they have sponsored since the early 1990s that has led to the understanding we have of radon entry factors and mitigation approaches for Guam.

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Anderson Air Force Base and the use of data that was acquired through innovative research they have sponsored.

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Dangkolo na si Yu'os ma'ase'