



The Pennsylvania Housing Research Center

PHRC Year in Review

July 2022 – June 2023

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I. Introduction

The purpose of this document is to provide a summary of activities the Pennsylvania Housing Research Center has pursued and products that have been delivered between July 1, 2022 and June 30, 2023.

Each year, the Pennsylvania Housing Research Center (PHRC) seeks to conduct a series of projects that collectively satisfy the following criteria. Projects should:

- meet the needs of the residential construction industry and the housing consumer in Pennsylvania;
- be consistent with the mission and goals of the PHRC;
- be affordable and feasible, given the resources available and the prevailing constraints on time, expertise, and facilities; and
- contribute to a balanced program of projects that addresses both the long- and the short-term needs of the industry.

The projects undertaken were developed with input and assistance from the PHRC’s Industry Advisory Council (IAC). This body consists of builders, developers, design professionals, code officials, manufacturers, suppliers, remodelers, and industry associations, as well as state and federal agencies. After a thorough discourse at the spring IAC meeting in April 2022, the members of the IAC voted on projects they felt were the highest priority for the industry.

The result of this input was the “*PHRC Project Plan, July 2022 – June 2023*,” which outlined projects that the PHRC would undertake during this time period. The plan included only those projects that were to receive funds provided to the PHRC by the Commonwealth of Pennsylvania through Uniform Construction Code (UCC) permit fees. When appropriate, the PHRC attempts to use UCC permit fee funding to leverage outside support. It should also be noted that the PHRC undertook an array of additional projects that did not receive any UCC permit fee funds. Some of these projects are included in this report but are identified as having no support from the UCC permit fee funds.

Through the Memorandum of Understanding that Penn State has with the Department of Community and Economic Development (Contract #27-872-0001), the PHRC is required to submit to DCED an annual work plan and an annual report summarizing the activities for the previous year with respect to the fee. This “Year in Review, 2022-2023” is submitted to meet the requirement of an annual report.

A. PHRC Organizational Chart

Figure 1 shows the current PHRC organizational chart.

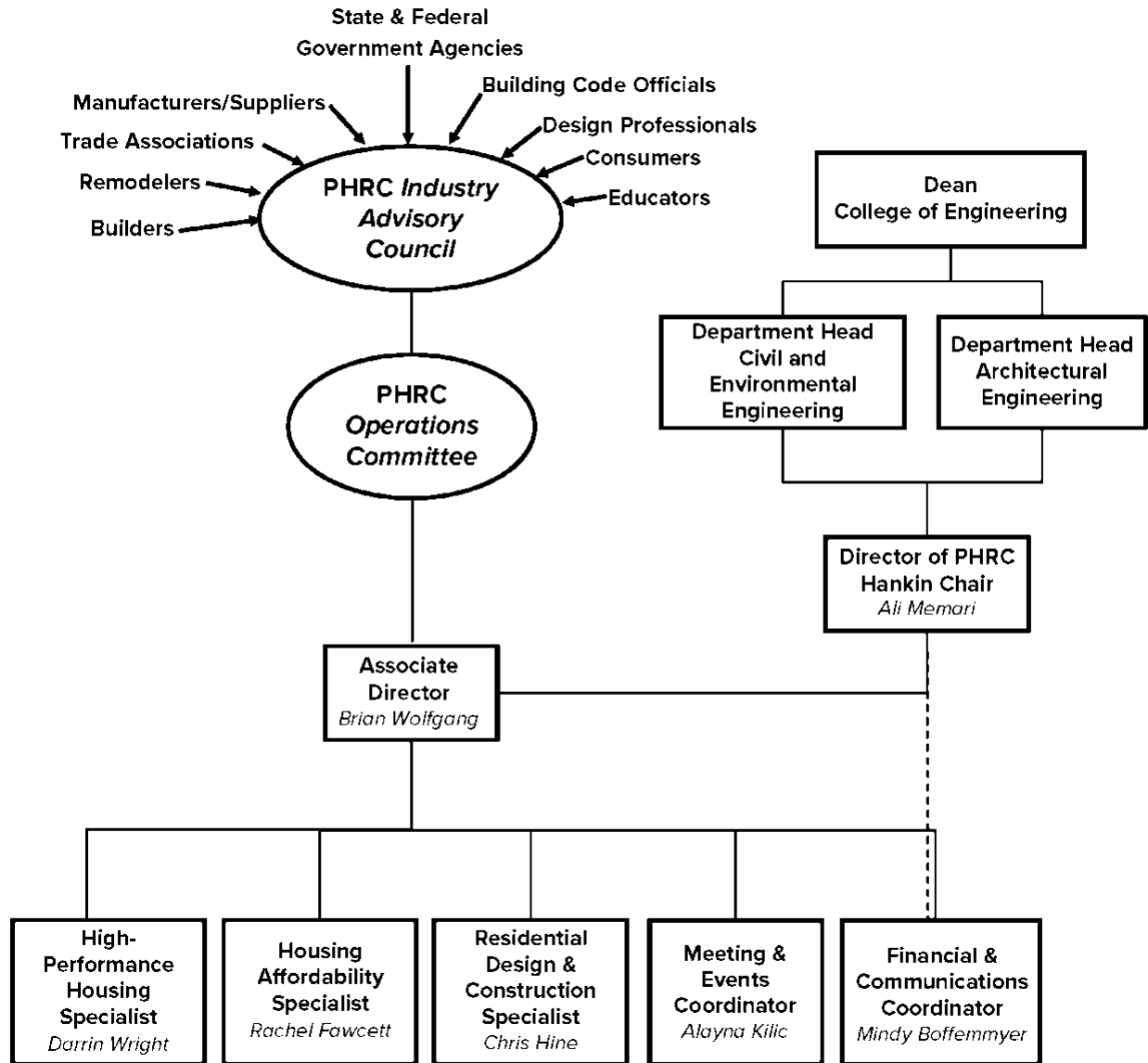


Figure 1. PHRC Organizational Chart

B. PHRC Staff Changes

The PHRC staff experienced substantial changes since the publication of the 2021-22 Year in Review. To summarize these changes:

- Darrin Wright was hired as the PHRC High-Performance Housing Specialist in July 2022.
- Tracy Dorman, longtime PHRC Meeting & Events Coordinator, retired from the PHRC effective June 30, 2023.
- Alayna Kilic was hired as the PHRC Meeting & Events Coordinator, effective July 1, 2023.
- A new position was created on the PHRC team in response to opportunities for externally funded weatherization training. This position is the PHRC Housing Affordability Specialist. Rachel Fawcett was hired into this position in June 2023.
- Mindy Boffemmyer was hired as the PHRC Financial & Communications Coordinator, effective September 14, 2023.

II. Training, Technical Assistance, & Outreach

The PHRC has a mandate to transfer knowledge by providing necessary training and education to the wide variety of groups that make up the housing industry. The initiatives described below address recommendations from the PHRC’s IAC and reflect the current needs within the industry.

Counting workshops, webinars, speaker services, and conferences, the PHRC provided 30 educational programs to 1,974 individuals during this reporting period (see Table 1). Additional content, such as on-demand courses, continued to expand the range of services offered by the PHRC team.

Table 1. Summary of PHRC Training Programs for the 2022-23 Project Year

| PROGRAM | Activities for 2022-23 | |
|--------------------------|------------------------|----------------|
| | # of Events | # of Attendees |
| Speaking Engagements | 13 | 309 |
| Workshops | 4 | 25 |
| PHRC Housing Conference | Day 1 | 124 |
| | Day 2 | 109 |
| Webinars | 10 | 1,142 |
| PHRC Construction Summit | 1 | 265 |
| TOTAL | 30 | 1,974 |

A. Externally Hosted Training

Description: The PHRC has developed and maintains a wide array of training for many sectors of the construction industry with a focus on residential construction. These programs are intended to address technical issues facing the industry. The intended audience for these programs includes builders, remodelers, trade contractors, design professionals, educators, and building code officials. Additionally, the PHRC can customize programs to better meet the needs of an industry partner. As appropriate, AIA Learning Units (LUs) for architects, PA Labor & Industry contact hours and International Code Council (ICC) credit hours for code officials, NARI credits for remodelers, and PA Professional Development Hours (PDHs) for engineers are offered.

The PHRC seeks to partner with relevant outside organizations whenever possible. These industry partners may include trade associations such as the Pennsylvania Builders Association or their local associations, professional associations, building code associations, as well as the Pennsylvania Construction Codes Academy (PCCA). For externally hosted training, these partners, groups, and organizations request specific topics to be covered in a program that may vary in length from 30 minutes to full-day offerings.

To further differentiate between the types of externally hosted training that the PHRC offers, each program is classified as either a speaking engagement or a workshop. Both types of programs may be delivered in-person or online. These program categories are defined below:

- 1. Speaking Engagements:** The PHRC defines speaking engagements as externally hosted training programs that are two hours or less in length. Generally, these programs are based on existing content that can be modified slightly to meet the needs of the host organization. The PHRC will continue to offer one speaking engagement at no cost to groups and organizations within Pennsylvania during each calendar year. Subsequent speaking engagements typically involve an additional negotiated fee.

Occasionally, the PHRC team is invited to speak at conferences and symposia throughout the Commonwealth. These types of presentations are also considered speaking engagements, although they may involve additional content creation based on the specific event.

Report: During the 2022-23 project year, the PHRC team delivered 13 speaking engagements to 309 attendees. This lower level of activity is common during the year following a code change, as organizations are not as active in offering training. Table 2 shows a summary of these speaking engagements.

Table 2. Speaking Engagements during the 2022-23 Project Year

| Organization | Topic(s) | Date | Attendees |
|---|---|------------|------------|
| Lebanon County Builders Association | Moisture Management - the 4 Ds | 7/20/2022 | 6 |
| PennBoc Region 6 | 2006 Wall Bracing | 8/18/2022 | 30 |
| Home Builders Association of NEPA | UCC Update Part 1 | 9/13/2022 | 0 |
| Pennboc | Residential Energy in PA | 9/23/2022 | 18 |
| North Strabane Township | Residential Moisture Management: the 4Ds | 9/28/2022 | 40 |
| Westmoreland Professional Builders Assn | Energy Code Compliance in the Uniform Construction Code | 10/27/2022 | 15 |
| HBA of Bucks/Montgomery Counties | Residential Moisture Management: the 4Ds | 11/11/2022 | 16 |
| Keystone ASHI (American Society of Home Inspectors) | A Comprehensive Deck Design from Footings to Guards: Learning from the Past | 12/5/2022 | 10 |
| Lebanon County Builders Association | Comprehensive Deck Design from Footings to Guards: Learning from the Past | 12/13/2022 | 4 |
| PFS Corporation | Air Sealing Requirements for Factory-Built Construction Systems | 1/12/2023 | 70 |
| Pennsylvania Housing Research Center (PHRC) | Federal, State, and Local Codes | 5/3/2023 | 50 |
| Westmoreland Professional Builders Assn | PHRC and What We Do | 5/18/2023 | 35 |
| Envinity, Inc. | Building Envelope Design and Code Compliance | 6/15/2023 | 15 |
| Total | | 13 | 309 |

2. **Workshops:** The PHRC defines workshops as externally hosted training programs that are greater than two hours in length, up to a full day. These programs may be based on existing training content but often involve extensive content creation. Workshops typically involve a negotiated fee based on travel, accommodations, and the extent of content creation needed to prepare for the program.

Report: During the 2022-23 project year the PHRC team delivered four workshops in partnership with the Pennsylvania Construction Codes Academy. Each workshop was delivered online via Zoom. Table 3 shows a summary of these workshops.

Table 3. Workshops during the 2022-23 Project Year

| Organization | Topic(s) | Date | Attendees |
|--|--|-------------|------------------|
| Pennsylvania Construction Codes Academy (PCCA) | Residential Energy in PA | 3/20/2023 | 4 |
| Pennsylvania Construction Codes Academy (PCCA) | Residential Deck Design & Construction | 4/3/2023 | 11 |
| Pennsylvania Construction Codes Academy (PCCA) | Residential Energy in PA | 4/4/2023 | 5 |
| Pennsylvania Construction Codes Academy (PCCA) | Residential Energy in PA | 6/20/2023 | 5 |
| Total | | 4 | 25 |

B. PHRC Hosted Training

Description: The PHRC hosts a variety of training activities, including online webinars, on-demand platforms for education, and in-person conferences. The scope of effort for these programs varies depending on the year, as some programs are only offered every other year. In addition, external factors, such as changes to the Pennsylvania Uniform Construction Code, may increase activity in specific areas.

- 1. PHRC Webinar Series:** The PHRC continues its successful webinar series. Webinars are delivered live for continuing education credit, and they are archived for on-demand viewing without continuing education credit. Topics are listed below. One PA Labor & Industry contact hour is offered for each webinar for PA code officials. As appropriate, AIA LUs for architects, ICC credit hours for code officials, NARI credits for remodelers, and PA PDHs for engineers are offered.

Report: During the 2022-23 project year the PHRC team delivered 10 webinars to a total of 1,142 attendees. Table 3 shows a summary of the 2022-23 webinar season.

Table 4. Webinars during the 2022-23 Project Year

| Organization | Date | Attendees |
|--|------------|--------------|
| A Comprehensive Deck Design from Footings to Guards: Learning from the Past | 9/13/2022 | 110 |
| Attic Ventilation Understanding the Why | 10/11/2022 | 137 |
| Walls That Work | 10/27/2022 | 111 |
| On-Lot Alternative Technologies Sewer Systems | 11/15/2022 | 84 |
| Best Practices for Understanding, Diagnosing, and Avoiding Problems in Polyurethane Foam Installatio | 12/13/2022 | 102 |
| Air SEaling Solutions for Attached Homes | 1/10/2023 | 178 |
| Balanced Ventilation: Understanding the Options | 2/14/2023 | 129 |
| The Cost of Airtight Homes | 4/11/2023 | 133 |
| Comfort in a Bonus Room? It's in the Details | 4/27/2023 | 74 |
| Land Use Planning and Regulation in Pennsylvania: Trends, Challenges, and Opportunities | 5/9/2023 | 84 |
| Total | 10 | 1,142 |

- 2. PHRC On-Demand Courses for Continuing Education:** The PHRC continues to partner with Penn State Extension to offer recorded webinars in an on-demand format. This format utilizes knowledge checks and a final quiz to satisfy continuing education requirements and provides a certificate of continuing education upon completion for a fee. The PHRC team will continue to deploy webinars that are developed and delivered internally through this on-demand platform.

Report: The PHRC team worked with ODL to develop four on-demand courses through Penn State Extension bringing the course total to twenty-one. Building code officials are the primary audience completing the courses. On average, registrants complete two courses per year. During the 2022-23 project year there were 27 course completions by 13 participants.

- 3. Annual PHRC Housing Conference:** The PHRC continues to organize, promote, and conduct the industry-focused conference. This conference has been held annually since 1992 and has established a reputation as the premier program focusing on technical issues of housing and land development in Pennsylvania. The conference brings together the building community (builders, remodelers, design professionals, educators), regulators (planners, building code officials, township engineers, DEP and conservation district staff, etc.), and others involved in the residential construction industry.

Report: The 2023 PHRC Housing Conference was held on March 1-2, 2023, at The Penn Stater Hotel & Conference Center in State College, PA. Both days included exhibitors during breaks to highlight products and services relevant to attendees.

Day 1: Day 1 of the 2023 PHRC Housing Conference started off with a keynote address from Emily Mottram, Mottram Architecture, entitled “The Pretty Good House.”

The following tracks and sessions were offered:

- Codes & Construction
 - “Industrialized Housing Program Update at the PA DCED” by Mike Moglia
 - “Insulated Precast Concrete Foundations & Walls” by Ed Helderman
 - “Debunking Duct Leakage Myths & Misconceptions in Frost Belt Homes” by Brendan Reid
 - “Residential Construction & the PA UCC” by Walt Schneider & Matt Keggs
- High-Performance & Offsite Construction
 - “Creating & Maintaining the 4 Critical Control Layers in High-Performance Homes” by Nick Shaw
 - “2020 National Green Building Standard (NGBS) Overview” by Cindy Wasser
 - “Working Through the Mechanical Ventilation Section in the 2018 IRC” by Szabi Fekete
 - “Residential Design with Structural Insulated Panels” by Chris Bloom
- The PHRC held a networking event titled “Networking on the Exhibit Floor” on the evening of March 1. This reception included conference speakers, attendees, and PHRC Staff and allowed for industry discussion on the day’s sessions. At this event, attendees were able to have productive discussions with industry exhibitors while also reviewing the day’s sessions with other attendees. Emily Mottram held a book signing for *The Pretty Good House* and Penn State students shared their impressive work from the NAHB Student Competition and the DOE Solar Decathlon Design Challenge.

Day 2: Day 2 of the 2023 PHRC Housing Conference included:

- Weatherization & Building Science
 - “Healthy Home: All Control Layers Working Together” by Kaylen Handly
 - “Weatherization 101: Opportunities for Energy Reduction in Existing Buildings” by Jack Wilson
 - “Decisions, Decisions: Navigating Options for Next-Level Air Sealing” by Brian Wolfgang
 - “The Heat, Air and Moisture House (H.A.M. House) by Andrew Woodruff
- Land Development & Planning
 - “Residential Housing Development Due Diligence” by Rebecca Morris & David Young

- “MS4 Permit Compliance: Best Practices” by Juni Alam & Tyler Erb
- “How Do Current Stormwater Management Regulations Affect the Housing Industry?” by Kara Kalupson
- “Short Term Rentals and Other Evolving Topics in Land Use Law” by Isaac Wakefield & Lee Stinnett
- Day 2 concluded with a combined afternoon plenary titled “Sunshine: Solar Energy Planning, Problems, and Perspectives” by Thomas Murphy & Steven Thomas

Table 5. Attendees at the 2023 PHRC Housing Conference

| Event | Attendees |
|---|-----------|
| Day 1 (March 1) | 124 |
| Day 2 (March 2) | 109 |
| Networking on the Exhibit Floor Reception | 91 |

4. Residential Building Design & Construction Conference (RBDCC): The PHRC organizes, promotes, and conducts the research-focused RBDCC in even numbered years. The RBDCC provides a unique forum for researchers, design professionals, manufacturers, and builders to keep up to date on the latest advancements and discuss their own findings, innovations, and projects related to residential buildings. RBDCC sessions consist of technical paper or poster presentations on recent research and innovations related to residential buildings. The RBDCC is focused on various types of residential buildings, including single- and multi-family dwellings, mid-rise and high-rise structures, factory-built housing, dormitories, and hotels/motels. Full papers are published in a conference proceedings.

The process to prepare for the biennial RBDC Conference is a two-year effort led by Ali Memari. This process includes, but is not limited to, the following tasks:

- Coordinating and negotiating event space
- Announcing and promoting a call for submissions and accepting abstract submissions for subsequent review
- Communicating reviews and deadlines to RBDCC authors
- Accepting final paper, presentation, and poster submissions
- Coordinating sessions with speakers and moderators
- General event logistics and planning

Report: The planning process for the 2024 RBDC Conference began in earnest during the 2022-23 project year. Keynote speakers were secured and a call for abstracts was published in spring 2023. By the time that the abstract submission process closed, 131 abstracts had been received. Paper submission will take place during fall 2023 with the peer review process to occur thereafter.

5. **PHRC Construction Summit:** The PHRC periodically organizes, promotes, and conducts the student-focused PHRC Construction Summit or similar events. This event is an effort to support secondary career and technology education programs through live in-person training, online training, and on-demand training. In past iterations, this event was hosted as a synchronous online offering with short technical presentations from external speakers and PHRC staff.

Report: The 2022 PHRC Construction Summit was held on December 8, 2022, and included four 30-minute sessions with 15-minute Q&A periods following each session. The sessions were presented twice, once in the morning and again in the afternoon.

In total, 265 participants, representing eight different secondary Career and Technical Education institutions across Pennsylvania, registered for this event.

C. Publications & Content Creation

Description: The PHRC leverages the technical expertise of staff members, along with the expertise of strategic external partners, to produce content for publication and future PHRC training programs. This initiative also includes the development and maintenance of online delivery platforms for article and video publication.

- 1. Written Content:** The PHRC produces written publications as appropriate, including both internally and externally published work. Examples of internal publications include Builder Briefs, research reports, technical flyers, and online articles. Examples of external publications include scholarly journal articles, conference proceedings, magazine and trade publication articles, and other general interest articles upon request.

This initiative includes the ongoing development and maintenance of the PHRC online article database that can be accessed through the PHRC website. This database allows the PHRC team to publish a range of types of written work, including general industry announcements and technical articles.

Report: During the 2022-23 project year, the primary objective regarding written content was to prepare for the launch of the PHRC News site. This site, otherwise referred to as the online article database, was launched in September of 2023 and contains technical articles, PHRC announcements, and general industry news. Content relating to the following topics was developed ahead of this launch:

- a. Mechanical ventilation:** The PHRC worked with Rick Karg, a subject matter expert in residential mechanical ventilation design and installation. Rick developed an 8-part series on mechanical ventilation which includes details on the technical background of indoor air quality, general ventilation strategies, as well as current code requirements for ventilation.
 - b. Understanding and decoding heat gain/loss calculations:** The PHRC developed written content relating to the need for permit applicants to supply heat gain/loss calculations relating to the project design. This content aims to provide permit applicants with some additional technical context to better understand the need for this calculation.
- 2. Video Content:** The PHRC continues to increase internal capacity to develop video content from demonstrations, site visits, and other live events. This content is captured, edited, and published in a manner that supports broader PHRC initiatives and future training programs. Example of deliverables related to video creation include the publication of short “toolbox talks” for the building community, recording of presentations for secondary programs, and capturing construction processes through live demonstration.

Report: The PHRC team continued to increase the use of video capture and sharing for online and in-person content delivery. Some examples of videos created in 2022-23 include window flashing demonstrations, air flow fundamentals using balloons, and infrared imagery during various climatic conditions.

D. Technical Assistance, Technology Transfer, & Outreach

Description: The PHRC works to get technical information, resources, and publications to builders, remodelers, design professionals, building code officials, and others involved in the residential construction industry in new and innovative ways. This often involves leveraging existing relationships, as well as developing new relationships, with other organizations in the residential construction industry.

1. **General Outreach Activities:** Through our general outreach initiatives, the PHRC pursues activities to keep industry professionals up to date on technical issues, as well as informed on the services and publications the PHRC provides. These activities may include email and social media campaigns, phone calls, and the PHRC’s website. Our general outreach also involves attending relevant industry meetings and serving as a technical resource to legislative committees as needed.

Report: The PHRC team engaged with the industry on various fronts, including through attendance at various organizations’ meetings and participation in a multitude of boards, councils, and committees in service to the residential construction industry. In addition, the lists below outline a portion of the scholarly efforts related to the residential construction industry through the guidance of the Hankin Chair and Director of the PHRC.

a. Journal Papers

- i. Duarte, J. P., Duarte, G., Brown, N., Nazarian, S., Memari, A., and Bilen, S. G., and Radlinska, A., (2023). “Designing a Habitat for 3D Concrete Printing in the Permafrost Regions,” *JOELHO - Journal of Architectural Culture* No. 14 (2023), 2023-07-13, Special Issue on “Digital Culture. What’s Next?”, Published 071323, pp. 49-70, DOI — 10.14195/1647-8681_14_3.
- ii. Bello, N. D. and Memari, A. M., (2023). “A Structural and Thermal Comparative Review of 3D-Printed Wall Shapes,” Published 061923: *Designs* Vol. 7, No. 80, 35p., 80; <https://doi.org/10.3390/designs7030080>.
- iii. Binega, E. and Memari, A. M., (2023). “Learning from Historical Building Construction in Sub-Saharan Africa to Adapt for Green 3D Printing of Houses,” *Journal of Green Building* Vol. 18, No.2, 2023, pp. 3-28. <https://doi.org/10.3992/jgb.18.2.3>.
- iv. Duarte, G., Duarte, J. P., Memari, A. M., Brown, N., Gevaudan, J. P., (2023). “Towards a Model for Structural Performance in Concrete Printing Based on Buildability and Toolpath Design,” *Building Engineering* Vol. 69, No. 15, June 2023, 106325; <https://doi.org/10.1016/j.jobbe.2023.106325>.
- v. Moeini, M., Brown, N., and Memari, A. M., (2023). “Estimating Hurricane-Induced Vertical Surge and Wave Loads on Elevated Coastal Buildings Based on CFD Simulations and Ensemble Learning,” *Elsevier Journal of Coastal Engineering* Vol. 183, August 2023, 104325; <https://doi.org/10.1016/j.coastaleng.2023.104325>.
- vi. Moeini, M. and Memari, A. M., (2023). “Review of Hurricane-Induced Failure Mechanisms in Low-Rise Residential Buildings: Knowledge Gaps and Future

Directions,” *ASCE Natural Hazard Review*, Published online 1/12/23; Vol. 24, No. 2, May 2023, 23p; <https://doi.org/10.1061/NHREFO.NHENG-1544>. DOI: 10.1061/NHREFO.NHENG-1544.

- vii. Bello, N. and Memari, A. M., (2022). “Comparative Review of the Technology and Case Studies of 3D Concrete Printing of Buildings by Several Companies,” *MDPI Buildings*, Special Issue on Advances in Additive Manufacturing and Construction 4.0, Published 12/31/22, Vol. 13, No. 106, 33p., <https://doi.org/10.3390/buildings13010106>.
- viii. Memari, A. M., Solnosky, R., and Hu, C., (2022). “Multi-Disciplinary characteristics of Double-Skin Facades for Computational Modeling Perspective and Practical Design,” *MPDI Buildings* Special Issue on Advanced Residential and Commercial Building Envelope Systems Evaluation, Published 9/30/22, Vol. 12, 1576, 33p., <https://doi.org/10.3390/buildings12101576>.
- ix. Kamel, E., and Memari, A. M., (2022). “Residential Building Envelope Energy Retrofit: Methods, Simulation Tools, and Example Projects: A Review of the Literature,” *MPDI Buildings*, Special Issue Advanced Residential and Commercial Building Envelope Systems Evaluation, Vol. 12, No. 7, 954, 28p; Published July 5, 2022, <https://doi.org/10.3390/buildings12070954>.
- x. Hojati, M., Memari, A. M., Wu, Z., Li, Z., Zahabi, M., Park, K., Nazarian, S., and Duarte, J. P., (2022). “Barbed-Wire Reinforcement for 3D Concrete Printing,” *Elsevier Automation in Construction* Vol. 141, 12p., Published September 2022, 104438, <https://doi.org/10.1016/j.autcon.2022.104438>.
- xi. Jellen, A. C. and Memari, A. M., (2023). “Structural Design of a Single-Family Residential Dwelling Using Cross-Laminated Timber (CLT),” Chapter in Book: *Sustainable Built Environment*, IntechOpen, London, United Kingdom, Guest Editor: Ying-Fei Yang, Published April 2023, 22p. ISBN: 978-1-83768-587-5. <file:///C:/Users/amm7/Downloads/86770.pdf>.
- xii. Habibi, S., Obonyo, E., and Memari, A. M., (2023). “Advancing the Use of Bamboo as a Building Material in Low Income Housing Projects in Kenya,” Chapter for the Book: *Bamboo and Sustainable Construction*; Guest Editor: Felipe Luis Palombini, and Fernanda Mayara Nogueira, Springer; Published March 2023, pp. 133-155; <https://link.springer.com/book/9789819902316>; ISBN 978-981-99-0231-6.

b. Conference Presentations

- i. Cheng, H. (Presenter), Radlinska, A., Memari, A., Duarte, J., Nazarian, S., and Bilen S., (2023). “Potential Use of Granulated Cork as Sand Replacement in Preparing Eco-Friendly 3D Printed Lightweight Concrete,” 13th Advances in Cement-Based Materials, June 14-16, 2023, Columbia University, NY.

c. Posters

- i. Cheng, H., Radlinska, A., Duarte, J. P., Nazarian, S., Memari, A., and Bilen, S. G., (2022). “Novel Mixture Design Method for 3D printing Eco-Friendly Concrete

Using Granulated Cork,” Poster presented at Materials Day 2022 -- Impacting Society, October 20-21, 2022, Penn State Materials Research Institute, held at HUB.

- ii. Duarte, G., Duarte, J. P., Memari, A., Brown, N, and Gevaudan, J. P., (2022). “Towards a Model for Buildability in 3D Concrete Printing Based on Material Properties,” Materials Day 2022 Conference, October 20-21, 2022, Penn State Materials Research Institute, Penn State University.
- iii. Cheng, H., Radlinska, A., Duarte, J. P., Nazarian, S., Memari, A., and Bilen, S. G., (2022). “Novel Mixture Design Method for 3D Printing Eco-Friendly Concrete Using Granulated Cork,” Poster Presentation at International Invention and Technology Exhibition, InnoWings 2022 Exhibition, October 20, 2022, Arena Lubin, ul. Stadionowa 1, Poland; organizer: International Invention and Technology Exhibition INNO WINGS.
- iv. Binega, E. and Memari, A. M., (2022). “Using Carbon-negative Hempcrete to 3D Print Environmentally Friendly Residential Houses,” Poster Presentation at The Pennsylvania Hemp Summit, November 15, 2022, Harrisburg, PA, Organized by: Pennsylvania Department of Agriculture and Team Pennsylvania Foundation.

2. **PCCA Symposium & Other Events:** The PHRC works upon request with the PCCA to plan, develop, and deliver online and in-person events in support of PCCA initiatives.

Report: The PHRC has increased general collaborative activities with the PCCA staff, including discussions for future PCCA symposia. While these symposia were not offered during the 2022-23 project year, the renewed emphasis on online course delivery has revived the relationship between the two organizations.

3. **Annual Magazine:** The PHRC annual magazine is sent electronically to PHRC members and stakeholders to keep them up to date on recent PHRC activities and to promote upcoming events. Additionally, it is archived on the PHRC website for public viewing.

Report: For the 2022-23 project year, the PHRC magazine was published in the fall to provide a timely update with the outcome of the previous year’s projects and with what to expect in the coming year.

4. **Support of Secondary Career & Technology Education (CTE) Programs:** The PHRC supports secondary education and CTE programs through a variety of outreach initiatives. Outreach activities are intentionally flexible based on the needs of these secondary programs but may include participation on occupational advisory committees, guest lectures in secondary program classrooms, development and promotion of video content for secondary students, and other activities as needed.

Report: The primary effort to support secondary CTE programs was highlighted in the PHRC-hosted training portion of this report and included the summary of the PHRC Construction Summit. In addition to this event, members of the PHRC continue to serve on various occupational advisory committees for local programs.

5. **Professional Women in Building (PWB):** The PHRC, in alignment with its current strategic plan, prioritizes gender equity in the residential construction industry through involvement with the NAHB Professional Women in Building (PWB) activities and initiatives. This effort includes relationship building, sharing of resources, speaking at school events, leveraging resources and contacts to bring opportunities to students, and soliciting feedback from instructors and administrators to better address their needs.

Report: The success of this initiative is demonstrated through the ongoing activities and success of the PWB Council within the Builders Association of Central PA. Members of the PHRC team serve this initiative through event planning and support of other activities, such as career exploration events.

6. **Support of the UCC RAC:** The PHRC supports the Uniform Construction Code Review & Advisory Council (RAC) and the public by serving as a general technical resource upon request.

Report: The PHRC was present at RAC meetings and supported the overall effort through the promotion of deadlines, as well as opportunities to contribute via public comment.

7. **Support of Standards:** The PHRC has developed standards to respond to industry demand. Each of these standards requires training and timely technical assistance for local governments, builders/developers, design professionals, and contractors. All of these standards are available electronically for free. Education on these standards is provided through various training programs as requested and technical assistance is provided through telephone and email support by the PHRC. The current PHRC standards include:

- 2021 Pennsylvania Alternative Residential Energy Provisions
 - Compliance Worksheet for the 2021 Pennsylvania Alternative Residential Energy Provisions
- Foundation Systems for Relocated Manufactured Housing

Report: The PHRC provided training on the 2021 Pennsylvania Alternative Residential Energy Provisions through conference sessions and speaking engagements.

8. **Strategic Partnerships:** The PHRC seeks out new relationships and partnerships with peer organizations with activity in the residential construction industry. These partnerships are leveraged for the benefit of the PHRC audience and stakeholders. PHRC staff time is allocated in support of this overall initiative.

Report: The PHRC continued to experience success from ongoing networking and relationship building with other organizations, manufacturers, and companies. Examples of this ongoing effort include increased collaboration between the PHRC and the Clean Energy Center at Penn College through weatherization training.

III. Applied Research

An important function of the PHRC is to undertake or stimulate research and development on materials, products, procedures, and processes. These efforts may have a longer-term or a more fundamental focus than other projects, and they are typically completed under the supervision of the PHRC director Ali Memari. Projects in this category foster partnerships and draw on the expertise and strengths of the people and facilities available at Penn State.

1. State of the Art Review of Alternatives to Wood Stick-Built Framing

Description: With the shortage of skilled labor in home construction, the increasing price of lumber, and, currently, the sharp increase in gas and fuel prices, there is an urgent need to find ways to control the rising costs of building homes. Recent studies have already established advantages of using prefabricated wood framing panels for walls and trusses for rooves over conventional stick-built practice, in terms of labor savings and minimized material use and dumpster costs. However, while prefabricating the framing to make wall panels and roof trusses yields some benefits, there are still other options to explore. For example, instead of only prefabricating the wall framing, one can prefabricate the complete wall, including sheathing, air/vapor barrier, insulation (e.g., spray foam on interior, and rigid insulation on exterior), and optional windows installed within the panel. Similarly, it is possible to prefabricate floor panels assembled using floor joists/trusses (including pre-cut holes in the webs) and sheathing. It is also possible to prefabricate partial or complete attics made up of the assembly of roof trusses, insulation, sheathing, vapor barrier, roofing membrane, and shingles. Such an approach is a step closer to modularization, yet it allows custom design and construction of homes without the many constraints of full modular homes. Furthermore, other alternatives to wood stud framing exist that are worthy of comparison. Examples of such alternative prefabricated framing include structural insulated panels, cold formed metal framing, manufactured wood, and other innovative systems. This study will explore alternative framing systems and develop design and cost comparison of the selected systems with a traditional house design based on stick-built framing.

Deliverables: The result of this work will include a PHRC report.

Report: The upcoming "State-of-the-Art Review of Alternatives to Wood Stick-Built Framing" report is developing reviews of two-dimensional hybrid panelized construction systems/components. Hybridized systems typically incorporate multiple building component types in their makeup and often reduce the number of trades required on site. They can include multiple structural components, such as framing and sheathing, or can include other system components, such as those required for the building envelope. An example would be assemblies that incorporate weather resistant barriers or cladding. The panelized systems reviewed in this report are those primarily considered for the construction of wall, floor, and roof assemblies within single-family residential dwellings. The format of the project report will include a short discussion about the pros and cons of hybrid panelized construction in comparison to other forms of prefabricated construction, as well as light-framed construction methods. Additional introductory material will include a discussion of applicable building codes and the implications of model-driven prefabrication on hybrid panelized construction methods. Following the introductory material, approximately 6-10 systems identified through the literature study will be presented in the final report. The report will also include a matrix that summarizes the identified

systems, which will be ranked in terms of select criteria. Currently, the technical report is being worked on, and a draft document is expected to be complete near the end of October.

IV. Projected Budget

The PHRC receives funding from diverse sources, including contracts, grants, membership fees, fees for services, and the funds collected under Act 157 of 2006 and amended by Act 36 of 2017. To fulfill PHRC’s annual mission, the organization must raise additional revenue outside of Act 157 funds to complete its annual project load.

Prior to October 25, 2018, Act 157 of 2006 funds were collected through a \$4 fee on every building permit issued in the Commonwealth and dispersed through the Department of Community and Economic Development (DCED). PHRC received 50% of the collected permit fees minus a 7.5% administrative fee to DCED.

However, beginning on October 25, 2018, Act 36 of 2017 amended building permit fees to \$4.50, with PHRC being allocated 43.5% of the collected permit fee, minus a 3% administrative fee to DCED. As of April of 2020, DCED changed their fee collection process to only accept online payments by credit card or check for UCC permit fees, which allows for more expedient reporting to the PHRC.

Funds for the 2022-23 Project Year are based upon funds received from July 2021 through June 2022, which can be seen in Table 6 below.

Table 6. Summary of Act 157 Funds received during the 2021-22 FY (2022-23 PHRC Project Year)

| Collection Period | Amount Received |
|----------------------------|------------------------|
| Q1: July 2021 - Sept 2021 | \$152,914.06 |
| Q2: Oct 2021 - Dec 2021 | \$122,981.76 |
| Q3: Jan 2022 - Mar 2022 | \$135,680.75 |
| Q4: April 2022 - June 2022 | \$92,438.06 |
| Total | \$504,014.63 |

Expenses for the Act 157 Account (\$459,419.93) were less than the revenues (\$504,014.63) for the 2022-23 project year. The PHRC continues to be fiscally conservative due to broad housing market uncertainty but has increased strategic investments through various initiatives, such as external content development and a broader investment in weatherization training. Table 7 shows a breakdown of PHRC expenses for the 2022-23 Project Year allocated to the Act 157 Account.

Table 7. PHRC Expenses for the 2022-23 PHRC Project Year

| Category | Act 157 |
|----------------------------------|---------------------|
| Total Salaries | \$304,739.25 |
| Total Wages | \$0.00 |
| Total Student Wages | \$487.50 |
| Fringe Benefits | \$93,025.43 |
| Supplies and Materials | \$3,365.28 |
| Communications Services | \$1,110.88 |
| Travel & Meetings | \$21,000.29 |
| Publications | \$770.00 |
| Maintenance | \$0.00 |
| Consulting & Prof Svc | \$13,711.19 |
| Copies and Photographic Services | \$0.00 |
| Computer Services | \$49.74 |
| Purchased Services | \$7,200.00 |
| Equipment | \$10,448.00 |
| Computer Equipment | \$872.37 |
| Miscellaneous | \$2,640.00 |
| Total | \$459,419.93 |