Supplementary Information

Multi-hazard housing safety perceptions of those involved with housing construction in Puerto Rico

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S1. Survey (English)

Section 1. General Information

1. What is your job? (Choose one)
    a. Owner or employee of a hardware store
    b. Contractor, builder, or handyman
2. With which gender do you identify? (Choose one)
    a. Female
    b. Male
    c. Nonbinary or do not want to share
3. What is your age? __________
4. Which municipality do you live in? __________
5. If different from where you live, which municipality do you work in? __________
6. How long have you worked in construction or at a hardware store? __________
7. Was your house damaged during Hurricane Maria? (Choose one)
    a. No damage
    b. Yes, minor damage (e.g., roof panels ripped off)
    c. Yes, major damage (e.g., roof structure damage)
    d. Yes, destroyed
8. Was your house damaged during the 2019-20 earthquakes?
    a. No, no damage
    b. Yes, minor damage (e.g., cracks)
    c. Yes, major damage (e.g., pieces of concrete falling or bars exposed)
    d. Yes, destroyed (e.g., collapse)
9. Which types of housing construction have you worked on or helped with? (Select all that apply)
    a. I don't have any housing construction experience
    b. Working on an expansion or addition to a house
    c. Working on a housing repair or rebuild after Hurricane Maria
    d. Working on a housing repair or rebuild after the earthquakes
    e. General repair or rebuild, without relation to hurricanes or earthquakes
    f. General housing build
    g. Other, please explain: _____________
10. If you do have housing construction experience, what type of housing have you worked on?
    a. Wood house

b. Concrete house
c. House with concrete first story, wood second story
d. House with concrete first story, concrete second story, wood roof
e. Other, please explain: _____________

Section 2.A Hurricanes

1. If a hurricane similar to Hurricane Maria passed near your community, do you think an informally constructed **wood** house (built without permission and licenses) would be damaged?
    a. No damage
    b. Yes, minor damage (e.g., roof panels ripped off)
    c. Yes, major damage (e.g., roof structure damage)
    d. Yes, destroyed
2. If yes to question 1, what components do you expect to be damaged?
    a. Panel-fastener interface (Roof panels ripped off)
    b. Truss-to-wall connection
    c. Purlin-to-truss connection
    d. Wall collapse
    e. Other, please describe: __________
3. If a hurricane similar to Hurricane Maria passed near your community, do you think an informally constructed **concrete** house (built without permission and licenses) would be damaged?
    a. No, no damage
    b. Yes, minor damage (e.g., cracks)
    c. Yes, major damage (e.g., need to replace part of roof)
    d. Yes, destroyed (e.g., collapse)
4. If yes to question 3, what components do you expect to be damaged?
    a. Wall cracking
    b. Column cracking
    c. Other, please describe: __________

Section 2.B Earthquakes

1. If an earthquake like the one on January 7, 2020 occurred near your community, do you think an informally constructed **wood** house (built without permission and licenses) would be damaged?
    a. No damage
    b. Yes, minor damage (e.g., cracking)
    c. Yes, major damage (e.g., roof structure damage)
    d. Yes, destroyed
2. If yes to question 1, what components do you expect to be damaged?
    a. Truss-to-wall connection
    b. Column collapse
    c. Purlin-to-truss connection
    d. Roof collapse
3. If an earthquake like the one on January 7, 2020 occurred near your community, do you think an informally constructed **concrete** house (built without permission and licenses) would be damaged?
    a. No, no damage
    b. Yes, minor damage (e.g., cracks)
    c. Yes, major damage (e.g., pieces of concrete falling or bars exposed)
    d. Yes, destroyed (e.g., collapse)
4. If yes to question 3, what components do you expect to be damaged?
    d. Wall cracking
    e. Column collapse
    f. Block wall collapse
    g. Column cracking
    h. Stilt collapse
    i. Roof collapse
    j. Beam cracking
    k. Other, please describe: __________

Section 3.A: Wood – Understanding the reasons for damage

For each of the design or construction practices in this section, please indicate whether you believe they could lead to damage in hurricanes, earthquakes, both, or neither. Then, select the reason you believe others complete this practice.

1. Using untreated wood

   a. Do you believe this practice leads to damage in hazards? (Select any that apply)
      i. Hurricane
      ii. Earthquake
   b. Reason for practice:
      i. Technical construction capacity (e.g., construction knowledge)
      ii. Money
      iii. Material availability
      iv. Aesthetics
2. Insufficient roof or wall supports
   a. Do you believe this practice leads to damage in hazards? (Select any that apply)
      i. Hurricane
      ii. Earthquake
   b. Reason for practice:
      i. Technical construction capacity (e.g., construction knowledge)
      ii. Money
      iii. Material availability
      iv. Aesthetics
3. Not including hurricane straps
   a. Do you believe this practice leads to damage in hazards? (Select any that apply)
      i. Hurricane
      ii. Earthquake
   b. Reason for practice:
      i. Technical construction capacity (e.g., construction knowledge)
      ii. Money
      iii. Material availability
      iv. Aesthetics
4. Having a large roof overhang
   a. Do you believe this practice leads to damage in hazards? (Select any that apply)
      i. Hurricane
      ii. Earthquake

   b. Reason for practice:
      i. Technical construction capacity (e.g., construction knowledge)
      ii. Money
      iii. Material availability
      iv. Aesthetics
5. Too large/small roof slope
   a. Do you believe this practice leads to damage in hazards? (Select any that apply)
      i. Hurricane
      ii. Earthquake
   b. Reason for practice:
      i. Technical construction capacity (e.g., construction knowledge)
      ii. Money
      iii. Material availability
      iv. Aesthetics
6. Connecting roof panels directly to purlins
   a. Do you believe this practice leads to damage in hazards? (Select any that apply)
      i. Hurricane
      ii. Earthquake
   b. Reason for practice:
      i. Technical construction capacity (e.g., construction knowledge)
      ii. Money
      iii. Material availability
      iv. Aesthetics
7. Insufficient nails/screws
   a. Do you believe this practice leads to damage in hazards? (Select any that apply)
      i. Hurricane
      ii. Earthquake
   b. Reason for practice:
      i. Technical construction capacity (e.g., construction knowledge)
      ii. Money
      iii. Material availability

iv. Aesthetics

8. Using deteriorated materials
   a. Do you believe this practice leads to damage in hazards? (Select any that apply)
      i. Hurricane
      ii. Earthquake
   b. Reason for practice:
      i. Technical construction capacity (e.g., construction knowledge)
      ii. Money
      iii. Material availability
      iv. Aesthetics

Section 3.B: Concrete – Understanding the reasons for damage

1. Not including a ring beam in design
   a. Do you believe this practice leads to damage in hazards? (Select any that apply)
      i. Hurricane
      ii. Earthquake
   b. Reason for practice:
      i. Technical construction capacity (e.g., construction knowledge)
      ii. Money
      iii. Material availability
      iv. Aesthetics
2. Weak columns
   a. Do you believe this practice leads to damage in hazards? (Select any that apply)
      i. Hurricane
      ii. Earthquake
   b. Reason for practice:
      i. Technical construction capacity (e.g., construction knowledge)
      ii. Money
      iii. Material availability
      iv. Aesthetics
3. Large beam and column spacing

    a. Do you believe this practice leads to damage in hazards? (Select any that apply)
        i. Hurricane
        ii. Earthquake
    b. Reason for practice:
        i. Technical construction capacity (e.g., construction knowledge)
        ii. Money
        iii. Material availability
        iv. Aesthetics
4. Weak concrete mix
    a. Do you believe this practice leads to damage in hazards? (Select any that apply)
        i. Hurricane
        ii. Earthquake
    b. Reason for practice:
        i. Technical construction capacity (e.g., construction knowledge)
        ii. Money
        iii. Material availability
        iv. Aesthetics
5. Insufficient horizontal bed reinforcement in walls
    a. Do you believe this practice leads to damage in hazards? (Select any that apply)
        i. Hurricane
        ii. Earthquake
    b. Reason for practice:
        i. Technical construction capacity (e.g., construction knowledge)
        ii. Money
        iii. Material availability
        iv. Aesthetics
6. Weak/insufficient mortar
    a. Do you believe this practice leads to damage in hazards? (Select any that apply)
        i. Hurricane
        ii. Earthquake

   b. Reason for practice:
      i. Technical construction capacity (e.g., construction knowledge)
      ii. Money
      iii. Material availability
      iv. Aesthetics
7. Building with a thin roof
   a. Do you believe this practice leads to damage in hazards? (Select any that apply)
      i. Hurricane
      ii. Earthquake
   b. Reason for practice:
      i. Technical construction capacity (e.g., construction knowledge)
      ii. Money
      iii. Material availability
      iv. Aesthetics
8. Insufficient vertical reinforcement in masonry walls
   a. Do you believe this practice leads to damage in hazards? (Select any that apply)
      i. Hurricane
      ii. Earthquake
   b. Reason for practice:
      i. Technical construction capacity (e.g., construction knowledge)
      ii. Money
      iii. Material availability
      iv. Aesthetics

Section 4: Wood and concrete housing mitigation measures for hurricanes and earthquakes

1. Please select mitigation measures that you believe are important to increase the safety of informally constructed wood houses. (Check any and all that apply)
   a. Using tensioner cables on roof

        i. Important in hurricanes
        ii. Important in earthquakes
        iii. Important for both
        iv. Not important
    b. Using thicker roof panels
        i. Important in hurricanes
        ii. Important in earthquakes
        iii. Important for both
        iv. Not important
    c. Using thicker structural members
        i. Important in hurricanes
        ii. Important in earthquakes
        iii. Important for both
        iv. Not important
    d. Using hurricane straps
        i. Important in hurricanes
        ii. Important in earthquakes
        iii. Important for both
        iv. Not important
2. Please select the changes to design and construction practices that you believe are important to increase the safety of informally constructed concrete houses. *(Check any and all that apply)*
    a. Repair cracks in the roof or walls
        i. Important in hurricanes
        ii. Important in earthquakes
        iii. Important for both
        iv. Not important
    b. Adding reinforced concrete jackets around stilts
        i. Important in hurricanes
        ii. Important in earthquakes
        iii. Important for both
        iv. Not important

c. Ensuring housing designs have ring beams
    i. Important in hurricanes
    ii. Important in earthquakes
    iii. Important for both
    iv. Not important
d. Add metal reinforcement under the first floor (e.g., if the floor is raised by stilts)
    i. Important in hurricanes
    ii. Important in earthquakes
    iii. Important for both
    iv. Not important

Section 5: More information

1. Did you have any training on housing construction?
    a. No, I have no received any training on construction
    b. Yes, vocational school
    c. Yes, trained by a formal employer
    d. Yes, training from a non-governmental or governmental group
    e. Other, please describe: __________
2. Where do people go to find information on safe housing construction?
    a. Churches
    b. The government
    c. Hardware stores
    d. Friends, family, or neighbors
    e. Social media (e.g., Facebook or YouTube)
    f. Community-based organizations
    g. Other, please describe: __________
3. Please describe where you think people should go for information on safe housing construction? ____________________

S2. Statistics results

Tables S1–S4 show the results of Kruskal-Wallis rank sum tests of the relationship between respondent distance from prior hazards (Hurricane Maria's central path and the epicenter of the 2019–20 earthquakes) and expected level of housing damage to wood and concrete housing

Table S1. Kruskal-Wallis rank sum test of the relationship between respondent distance from Hurricane Maria's approximate central path and respondent expected level of wood housing damage in future hurricanes

Kruskal-Wallis chi-squared:	6.1528
df:	3
p-value:	0.8023

Table S2. Kruskal-Wallis rank sum test of the relationship between respondent distance from the 2019-20 earthquakes' epicenter and respondent expected level of wood housing damage in future earthquakes

Kruskal-Wallis chi-squared:	53.343
df:	3
p-value:	0.4997

Table S3. Kruskal-Wallis rank sum test of the relationship between respondent distance from Hurricane Maria's approximate central path and respondent expected level of concrete housing damage in future hurricanes

Kruskal-Wallis chi-squared:	12.449
df:	3
p-value:	0.256

Table S4. Kruskal-Wallis rank sum test of the relationship between respondent distance from the 2019-20 earthquakes' epicenter and respondent expected level of concrete housing damage in future earthquakes

Kruskal-Wallis chi-squared:	60.201
df:	3

p-value:	0.2614

Tables S5–S8 show the results of binomial logistic regression. These regressions test the relationship between construction experience level on expected housing component damage in future hazards. Construction experience has been coded as a binary variable to reflect "any" or "no" level of experience. These results predict whether a respondent has any construction experience based on which components they expect to fail in a future hurricane or earthquake. Table S5 shows wood housing in hurricanes, Table S6 shows wood housing in earthquakes, Table S7 shows concrete housing in hurricanes, and Table S8 shows concrete housing in earthquakes.

Table S5. Multinomial logistic regression results showing the relationship between construction experience level on expected wood housing component damage in a future hurricane

	logit	***Std. Error***	***z-value***	***p-value***
Intercept	0.389043	0.225635	1.7242	0.08467 .
Purlin-to-truss connection	0.412618	0.269927	1.5286	0.12636
Panel-fastener interface	0.023207	0.258686	0.0897	0.92852
Truss-to-wall connection	−0.213191	0.252088	−0.8457	0.39772
Wall failure	0.068587	0.371394	0.1847	0.85348

Log-Likelihood: −228.54; McFadden R^2: 0.0064045, Likelihood ratio test: chisq = 2.9462 (p.value = 0.56687)

Significance codes: 0.05 '.' 0.1 ' ' 1

Table S6. Multinomial logistic regression results showing the relationship between construction experience level on expected wood housing component damage in a future earthquake

	Estimate	***Std. Error***	***z-value***	***p-value***
Intercept	0.56896	0.161	3.5339	0.0004094 ***

Purlin-to-truss connection	−0.1564	0.28068	−0.5572	0.5773738
Column collapse	−0.4027	0.27055	−1.4884	0.1366367
Truss-to-wall connection	0.18445	0.24003	0.7684	0.4422348
Roof collapse	−0.17951	0.31574	−0.5685	0.5696758

Log-Likelihood: −219.67; McFadden R^2: 0.044935, Likelihood ratio test: chisq = 20.671 (p.value = 0.004289)
*Significance codes: 0 '***' 0.001*

Table S7. Multinomial logistic regression results showing the relationship between construction experience level on expected concrete housing component damage in a future hurricane

	Estimate	***Std. Error***	***z-value***	***p-value***
Intercept	0.4816239	0.1470393	3.2755	0.001055 **
Wall cracking	0.0042735	0.2377328	0.018	0.985658
Column cracking	−0.4078574	0.2975348	−1.3708	0.170441

Log-Likelihood: −228.76; McFadden R^2: 0.0054555, Likelihood ratio test: chisq = 2.5096 (p.value = 0.47356)
*Significance. codes: 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

Table S8. Binomial logistic regression results showing the relationship between construction experience level on expected concrete housing component damage in a future earthquake

	Estimate	***Std. Error***	***z-value***	***p-value***
Intercept	0.536207	0.219099	2.4473	0.01439 *
Roof collapse	0.559127	0.311297	1.7961	0.07247 .
Block collapse	−0.444453	0.29139	−1.5253	0.12719

Stilt collapse	0.135044	0.271671	0.4971	0.61913
Beam cracking	0.684982	0.292068	2.3453	0.01901 *
Column collapse	−0.688547	0.292334	−2.3553	0.01851 *
Wall cracking	−0.073665	0.286981	−0.2567	0.79742
Column cracking	0.581511	0.265035	2.1914	0.02823 *

Log-Likelihood: −219.67; McFadden R^2: 0.044935, Likelihood ratio test: chisq = 20.671 (p.value = 0.004289)

Significance codes: 0.01 '' 0.05 '.' 0.1 ' ' 1*