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TRANSDISCIPLINARY STRATEGIES FOR SUSTAINABLE HOUSING: WOMEN'S PARTICIPATION AND ALTERNATIVE CONSTRUCTION MATERIALS IN MARGINALIZED COMMUNITIES OF NORTHERN MEXICO

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ABSTRACT

Access to adequate housing continues to represent a major challenge in many urban areas of Latin America, particularly in communities affected by socioeconomic vulnerability and limited access to formal construction systems. This study proposes a transdisciplinary perspective that integrates social diagnosis, gender analysis, and experimental research on sustainable construction materials in order to explore new strategies for improving housing conditions in marginalized urban contexts. The research was conducted in the Cerro de la Campana neighborhood located in the metropolitan area of Monterrey, Mexico. A field study involving seventy-eight households was carried out to analyze housing conditions, family structure, and women's participation in housing-related decision-making processes. The results reveal that women frequently assume central roles in household management and community networks, which opens opportunities for collective self-construction initiatives. In parallel, an experimental exploratory phase evaluated the potential incorporation of supplementary cementitious materials such as fly ash, limestone, and volcanic pozzolan in mortar mixtures prepared according to ASTM C109 specifications. The results suggest that these materials could represent viable alternatives for reducing the environmental impact of construction materials while maintaining adequate mechanical performance. The integration of community participation and environmentally responsible construction technologies may contribute to more inclusive and sustainable housing solutions. The findings highlight the importance of combining social participation, gender inclusion, and technological innovation to address housing challenges in rapidly urbanizing regions.

KEYWORDS: Sustainable Housing, Self-Construction, Gender Participation,Supplementary Cementitious Materials, Urban Marginalization, Transdisciplinary Research.

1. INTRODUCTION

Access to adequate housing is widely recognized as a fundamental social right and constitutes an essential indicator in the analysis of multidimensional poverty. Despite progress in housing policies, many developing countries continue to face significant challenges associated with rapid urban growth, informal construction, and limited access to affordable housing solutions (UN-Habitat, 2020).

In Mexico, urbanization during the twentieth century significantly transformed the spatial distribution of the population. Metropolitan regions expanded rapidly as a consequence of industrialization and economic concentration, generating new demands for infrastructure, services, and housing (Garza, 2010). Monterrey represents one of the most dynamic metropolitan areas in the country, characterized by strong industrial activity and sustained population growth.

However, this accelerated development has also intensified housing inequalities. A considerable proportion of dwellings in Mexico have been constructed through incremental self-construction processes, frequently without technical supervision or formal architectural planning (Ward, 2015). While this strategy allows families to progressively improve their homes according to their economic capacities, it may also lead to structural deficiencies and reduced environmental performance.

At the same time, environmental concerns associated with the construction sector have become increasingly relevant. Cement production alone is responsible for approximately 7–8% of global carbon dioxide emissions, mainly due to the energy requirements and chemical reactions involved in clinker production (Scrivener, John & Gartner, 2018; Andrew, 2019). Consequently, the development of alternative construction materials and more sustainable production processes has become an important research priority.

Within this context, supplementary cementitious materials such as fly ash, blast furnace slag, limestone powder, and natural pozzolans have received considerable attention due to their capacity to partially replace Portland cement while maintaining adequate mechanical performance (Mehta & Monteiro, 2014). Their use not only reduces greenhouse gas emissions but also contributes to circular economy strategies through the reuse of industrial by-products.

Another key dimension in the analysis of housing conditions relates to gender roles. Women frequently play a central role in household organization and community support networks, yet they often face structural barriers that limit access to formal housing programs and financial resources (Chant, 2007; Moser, 2012).

Considering these interconnected social and environmental challenges, the present study proposes a transdisciplinary research approach integrating social analysis and materials science in order to explore sustainable housing alternatives for marginalized communities in northern Mexico.

2. SOCIAL AND ENVIRONMENTAL CONTEXT

Urban expansion in northern Mexico has generated significant pressure on housing systems. The metropolitan area of Monterrey concentrates a large proportion of the state population and economic activity, resulting in increasing demand for affordable housing and public services (Garza, 2010).

In many cases, families address housing needs through incremental self-construction strategies. These processes frequently involve informal labor networks and community support mechanisms that allow households to progressively modify or expand their dwellings according to available resources (Ward, 2015).

From an environmental perspective, the construction sector plays a major role in global resource consumption and carbon emissions. Cement production alone releases large quantities of CO_2 due to both energy consumption and chemical decomposition during clinker formation (Andrew, 2019).

One promising strategy to mitigate these environmental impacts involves the incorporation of supplementary cementitious materials derived from industrial processes or natural mineral sources. Materials such as fly ash and volcanic pozzolan have demonstrated the ability to improve the sustainability of cementitious systems while maintaining acceptable mechanical properties (Scrivener et al., 2018).

Despite these technological advances, sustainable construction practices are still predominantly implemented in large infrastructure projects or high-income housing developments. Extending these innovations to marginalized communities requires new frameworks that combine technological development with community participation and social empowerment.

3. METHODOLOGY

3.1 Social diagnosis of the study area

The first stage of the research involved a social diagnostic study carried out in the Cerro de la Campana neighborhood located in the metropolitan area of Monterrey. This area was selected due to its socioeconomic vulnerability and the presence of informal housing development.

A structured survey instrument was designed to collect information regarding household composition, housing characteristics, educational background, employment conditions, and participation in housing-related decision-making.

After preliminary pilot testing to refine the instrument, a total of 78 household surveys were conducted across several blocks of the community.

Figure 1: Location of surveyed households in Cerro de la Campana, Monterrey metropolitan area.

The survey results allowed the identification of key patterns related to housing conditions, family structure, and women's participation in household management.

3.2 Experimental evaluation of alternative construction materials

In parallel with the social analysis, an exploratory experimental study was carried out to evaluate the potential use of supplementary cementitious materials in mortar mixtures.

The materials employed included:

- Portland cement (CPO)
- Calcium sulfoaluminate cement (CSA)
- Fly ash (FA)
- Limestone powder (LS)
- Volcanic pozzolan (VP)
- Silica sand

Mortar mixtures were prepared following ASTM C109 specifications, maintaining a **cement:sand ratio of 1:2.75** and a **water-to-cement ratio of 0.4**.

Table 1: Composition of mortar mixtures.

Mix	CSA (%)	CPO (%)	CL (%)	CV (%)	PV (%)
CSA	100	–	–	–	–
CO50	50	50	–	–	–
CCL30	70	–	30	–	–
COCL2525	50	25	25	–	–
CCV30	70	–	–	30	–
COCV2525	50	25	–	25	–
CPV30	70	–	–	–	30

After casting, the specimens were pre-cured for 24 hours at controlled temperature conditions before being subjected to different curing regimes.

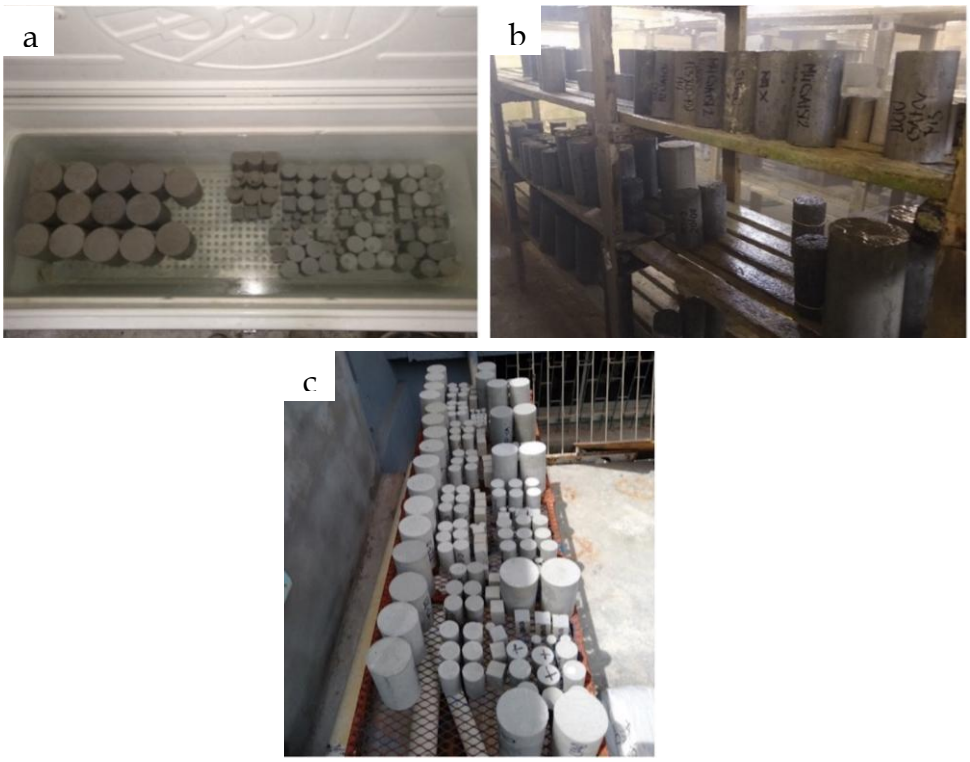

Figure 2: Experimental curing procedures applied to mortar specimens.

The curing conditions included:

- Water immersion curing
- Controlled humidity chamber curing
- Air curing under ambient conditions
- Combined curing involving initial immersion followed by air exposure

These curing regimes were selected to simulate environmental conditions commonly encountered in real construction scenarios.

4. RESULTS

4.1 Housing conditions and family structure

The social diagnosis revealed that women frequently assume central roles in household management and decision-making processes. In a significant proportion of surveyed households, women were identified as either the main economic providers or co-providers within the family structure.

Household composition typically ranged between three and four members, with most participants reporting between one and three children. The average age of respondents was approximately forty-eight years, indicating participation from both younger mothers and older women with long-term residence in the neighborhood.

Housing typologies were predominantly independent dwellings constructed incrementally over time. Most houses were built using concrete blocks or brick masonry combined with reinforced concrete roofing systems.

Figure 3: Representative housing conditions observed in the study area.

These findings illustrate the importance of incremental construction strategies and the long-term attachment of families to the neighborhood, as many residents reported having lived in the same house for several decades.

4.2 Performance of mortar mixtures

The experimental evaluation indicated that mortar mixtures incorporating supplementary cementitious materials can achieve acceptable performance under appropriate curing conditions. The compressive strength of the different mortar mixtures was evaluated following ASTM C109 specifications. The results obtained at 7 and 28 days of curing are summarized in Table 2.

Table 2: Compressive strength of mortar mixtures prepared with supplementary cementitious materials.

Mix	7 days (MPa)	28 days (MPa)
CSA	36.5	44.2
CO50	34.8	41.6
CCL30	33.1	39.7
COCL2525	32.5	38.9
CCV30	31.2	37.8
COCV2525	30.6	36.9
CPV30	29.4	35.7

The results indicate that mixtures containing supplementary cementitious materials developed adequate mechanical strength for potential use in non-structural housing applications. Although a reduction in compressive strength was observed when Portland cement was partially replaced, the values obtained remain within acceptable ranges for masonry mortars and low-rise construction.

Mixtures incorporating volcanic pozzolan and fly ash showed particularly promising performance, suggesting that these materials may represent viable alternatives for reducing the environmental footprint of cement-based materials while maintaining functional mechanical properties.

These findings are consistent with previous studies reporting the feasibility of incorporating industrial by-products and natural pozzolans in cementitious systems to reduce carbon emissions while preserving mechanical performance (Mehta & Monteiro, 2014; Scrivener et al., 2018).

5. DISCUSSION

The results of this research highlight the value of combining social and technological perspectives when addressing housing challenges in marginalized communities.

From a social standpoint, the central participation of women in household organization and community support networks represents an important opportunity for the implementation of collective self-construction initiatives. Empowering women through training programs related to sustainable construction techniques may facilitate the adoption of environmentally responsible building practices.

From an environmental perspective, the incorporation of supplementary cementitious materials offers promising possibilities for reducing the carbon footprint associated with construction materials. The reuse of industrial by-products such as fly ash also contributes to circular economy strategies by reducing waste accumulation.

These findings suggest that sustainable housing solutions should not be limited to technological innovation alone but must also incorporate social participation and community empowerment.

6. CONCLUSIONS

This research explored a transdisciplinary framework integrating social analysis and materials science to investigate sustainable housing alternatives in marginalized urban communities.

The results demonstrate that women play a fundamental role in household organization and community networks, highlighting the importance of incorporating gender perspectives into housing improvement strategies.

At the same time, the experimental evaluation of supplementary cementitious materials suggests that environmentally responsible construction materials can be incorporated into alternative housing solutions.

The integration of community participation, gender inclusion, and sustainable construction technologies represents a promising pathway for improving housing conditions while reducing the environmental impact of the construction sector.

Future research should focus on pilot implementation of these materials in real housing projects and the development of community training programs that strengthen local capacities for sustainable construction.

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