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Investigating Alternative Materials for Displacement Shelters, Using North-West Syria as an Example.

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Abstract: Syria is home to one of the most intense deteriorations of civilian livelihood and security, ranking in the bottom 5 of civil unrest indices consistently since the 2012 uprising (Maplecroft, 2021). As of 2022, Syria accounts for over 14 million FDIs, 6.9 million being IDPs, predominantly on the north-western coast. With extreme weather events occurring at greater frequencies, the failure of humanitarian organization aid, specifically the tents, must be investigated for their resilience. With limited access to resources, due to disturbed supply chains and boarder conflict, the opportunity to investigate alternative local resource streams, to better shelter environments, is presented. This report investigates the potential of using food waste by-products as an alternative resource stream, combined with vernacular construction methods. Coffee grounds, nut shells, date seeds and chickpea water were used in different combinations with conventional earth materials, and subject to thermal, moisture and load tests.

Keywords: climate resilience, displacement, shelters, alternative resource streams, materialization

1. Introduction

The recurrence of new insurgencies, such as within Syria, showcase the impeding results of political and environmental unrest, in which the influx of forcibly displaced individuals (FDI) remains at an upwards inclination. Additionally, the increased frequency of extreme weather events occurring globally set the expectation that not only will forcibly displaced individuals (FDI) increase, but the livelihood of those displaced will be even further compromised within refugee camps and settlements (RCS). Organisations, such as UNHCR and other small-scale non-profits, remain the main source of aid for FDI across the globe, providing various means of shelter and living assistance for households within planned and unplanned settlements. Humanitarian organisation tents (HOT), usually composed of tarpaulin or polycotton, are the most common solution distributed within RCS, with life expectancies of 6-12 months quoted by providers (UNHCR, 2021). This highlights the biggest concern for FDI relying on organisational solutions for their accommodation, as displacement durations are protracted to an average of 18 years per person or household (UNHCR, 2021). Given the prolonged residence of FDI, and insufficient performance of the tent materials, it is imperative that alternative materials are investigated to not only provide better livelihoods for FDI, but also reduce the environmental implications of waste plastic arising from deteriorated shelter envelopes (Don-Alvin Adegeest, 2022; Practical Action, 2022).

As of 2022, Syria accounts for over 14 million FDIs, 6.9 million being IDPs, predominantly on the north-western coast, a region frequently impacted by extreme weather events. With limited access to resources, due to disturbed supply chains and border conflict, the opportunity to investigate alternative local resource streams, to better shelter environments, is presented (UNHCR, 2021).

2. Literature Review

Syria has been categorised as 'high-fragility' to climate risk. With intensifying weather fluctuations, the regions vulnerability to drought, flood, wildfires, and frost is exacerbated (Shelter Cluster, 2022). This puts IDPs in an extremely vulnerable position as Shelter Cluster (2021) state that approximately one-third of all organisational structures deployed across NWS have experienced climate-related calamities, with tents deteriorating, collapsing, and exposing IDPs to poor health, comfort, and wellbeing (HCW) (OCHA, 2022a).

Access to natural resources for more durable builds, such as concrete, earth, and wood, are extremely limited to IDPs due to the various socio-political and environmental factors (Hardan, 2021). This catalyses the investigation into alternative resources that can be utilised in materialisation. Although food-stress is experienced across Syria, the region is still home to high food-waste, with study estimates of organic waste to be 70-72% nationally, for households (Don-Alvin Adegeest, 2022). It has been reported across RCS that, due to poor infrastructure and unplanned settlement, waste disposal is nonexistent, and remains on site. The utilization of waste-products in materials has been investigated in recent years, forming variants of bio-composites. Although these mixtures are typically formed of natural-reinforcements (such as kenaf) and polymer-based ingredients (such as lingin), implementation is not globally accessible. The technological aspects of extracting fibres and the lack of obtainability of biopolymers within Syria encourage a more honed-down approach of biocomposite adoption for shelter materials (Khoshnava et al, 2020). The integration of vernacular earthen-based construction methods, with FWBP as the natural reinforcements is presented, to utilize the resources IDPs will have access to. The following section will investigate the viability of this concept.

3. Methodology

3.1 FWBP Discovery

Investigation of the typical foods available to IDPs, via nutrition analyses, local crop, and food aid packages available across Syria was conducted to identify potential FWBP sources. The qualities and potential uses of each by-product ingredient were established. They were obtained locally and treated (crushed, air dried etc), in preparation for the next stages.

Table 1 FWBP Discovery

Material	***Treatment***	***Source***
Coffee Grounds	Air dried	Collected from coffee shops
Pistachio shells	Crushed with hammer	Collected through friends and family
Date seeds	Attempted to blend, however was unsuccessful so left as is	Collected through friends and family
Aquafaba	Poured from package, hand-whisked where applicable	Purchased from shop
Sand aggregate	Left as is, various granularity	Obtained from workshop
Soil	Left as is, with some straw	Obtained from workshop
Water	-	From tap

3.2 Composite Creation

To determine whether FWBP can serve as an alternative to vernacular materials, typical adobe blocks of clay, sand, and soil were made alongside the mix composites for comparisons. Before initiating the composite formation, an initial test was conducted to determine the material ratios. Varying ratios were tested beforehand in small batches to ensure limited material wastage. A ratio of **25% clay, 35% soil and 45% aggregate** was successfully selected as the standardised ingredient split. Based on this, a series of composite recipes were curated, utilising the ingredients decided upon in the discovery. The composite breakdown is shown in table 2, below.

Table 2 Composite Recipes

Sample Identification	**Composition**	**Method**
Adobe Block (ADB)	Soil (35%) Sand (40%) Clay (25%) Water Hydration	Dry ingredients mixed, then kneaded with clay as hydrated
Adobe Block, with coffee soil substitute, and aquafaba hydrator (ACA)	Coffee (35%) Sand (40%) Clay (25%) Aquafaba Hydration	Dry ingredients mixed, then kneaded with cay as hydrated with aquafaba
Composite Block of clay, aggregate mix, and coffee (CAC)	Coffee (35%) Sand (30%) Aggregate mix (10%) Clay (25%) Aquafaba hydration	Dry ingredients mixed, then kneaded with cay as hydrated with aquafaba
Composite Block of clay, aggregate mix, and subsoil mix (CAS)	Soil (20%) Coffee (10%) Sand (30%) Aggregate Mix (10%) Clay (25%) Aquafaba Hydration	Dry ingredients mixed, then kneaded with cay as hydrated with aquafaba

Once combined, the material mixtures were hand pressed into 5x5cm cube moulds, to provide standardised shape and volume. Nine samples of each mixture (9x4) were made, forming a total of 36 block. Each recipe then has three of each sample grouped together, and subject to one of three setting treatments: F (fridge) to mimic cooler temp, A (ambient) to mimic shoulder temps, and O (oven) to mimic hotter temps. This was done to established difference in seasons, as table 3, below, demonstrates.

Table 3 Block sample weight (g), categorised by treatment

Sample	**Fridge (1°C)**			**Ambient Conditions (22°)**			**Oven/incubator (36°)**		
ADB (x9)	240	210	206	231	220	209	240	235	226
ACA (x9)	175	169	164	172	169	167	192	168	163
CAC (x9)	121	117	109	124	116	106	120	119	106
CAS (x9)	128	118	103	125	118	107	125	117	109

3.3 Thermal Experiment

To test the thermal storage of the material samples, they were put in an environment chamber, at a temperature of 36°C and 46% RH to mimic typical summer conditions in NWS—using Aleppo and Idlib weather data (World Bank, 2020). Once the materials were subject to the conditions for approximately 24 hours, they were taken out and laid on a work bench, where surface temperatures were recorded for each sample, at 5-minute intervals, over the span of two hours. Values will be noted and reviewed to determine which material composite and treatment retained heat for the longest time period. (Curto et al, 2020; Saleh et al, 2021)

3.4 Moisture Experiment

Following the methods prescribed in various studies, one sample of each material block was selected and placed into the environment chamber at 79% RH and 36°C (Abdellatef et al., 2020). After subjection to the conditions for 24 hours, the blocks were removed and weighed on a scale, with values recorded and the difference in weight calculated.

3.5 Compression Experiment

This test will investigate the load-bearing trends of each composite block, where a stress-stain graph can be produced to investigate the material properties based on its deformation (Curto et al ,2020). Target values include the load expected during snowstorms, meeting the minimum value of 300N/m2, as per ISO 8937 stipulates for tents. The blocks will be put under a hydraulic press to see the load at which fractures occur.

4. Results

4.1 Thermal Results

The thermal monitoring showed no clear significant difference between the treatment types. The most distinguishable result was obtained by the ADB block, which appears to show the ADB-O have a lower dissipation rate than other treatments, with a shallower decline over time, as figure 1 shows. This contrasts the CAS-O results which appear to have the steepest slope between 5-45 minutes; this may be accounted for by the surface cracks on the samples for the CAS recipe. Besides small variations, the results from the thermal monitoring appear to intertwin, with only speculative conclusions to be drawn. From the plot trends, there is a potential that the ACA-CAC-CAS variant dissipated heat at a slower rate, achieving ambient conditions after 70 minutes, opposing the ADB performance. Integration of coffee has been reported as increasing the thermal performance of brick materials, the results from this experiment may suggest that there is a potential, however a more conclusive procedure must be conducted (Khoshnava et al 2017). Results are expected to be compromised by the condition of the materials, as surfaces recorded were not smooth. Szczepaniak (2022) investigated the correlation between the surface roughness of a block material, and the efficiency in thermal diffusivity reading. The report concluded that for rougher surfaces, with more cavities, the thermal readings could produce errors of up to 16.7%.

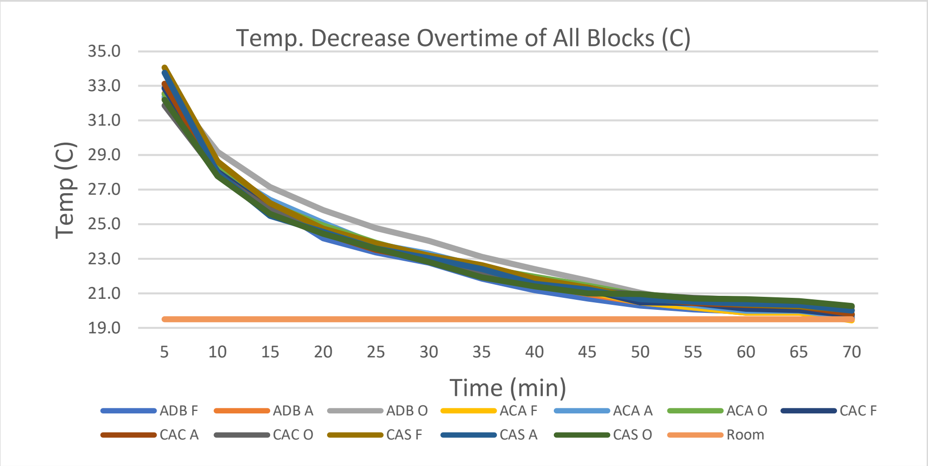


Figure 1 Thermal Diffusivity Results

4.2 Moisture Results

The results for the weight change of each block are illustrated in Figure 2, below. The variation in weight before and after exposure to high moisture levels (79%) varied from 0.3-1.8g. The greatest weight gain happened to the CAS-O block, at 1.8g. As indicated in the thermal analysis, this could be due to the uneven surface and cracks, which allows for greater water absorption into the material. Ordieres and Cultrone (2020) found that mixing clay with coffee grounds for typical bricks, the water retention was increased and thus the water retention was greater. Quesada, (2011) reported similar findings, where clay-bricks containing 30% wt-coffee increased the porosity and suction of the material. This demonstrates that the water evaporated during the O-treatment was vast, as exposure to humidity caused the greatest weight gain. As the most intact materials, ADB and ACA variants, experience a lower average weight gain, these results concur that the material cohesivity was lower for the FWBP-aggregate mixes with greater pore spaces. Though, the lowest weight gain is unexpectedly seen by the CAS-F variant. Due to the incohesive, coarse grain of the FWBP aggregate, it was expected the water content of the material would suffer greatest increase, as a more porous material. This may suggest that the composition of the block was taken up by the volume of the FWBP aggregates used. Alternatively, the results could indicate that the block was at its moisture-absorption capacity, as this material was subject to the cool, damp conditions of the fridge. This is further indicated as the F treatment for CAC and CAS obtained less weight increase than their O-treated constituents, which achieved the greatest weight gain.

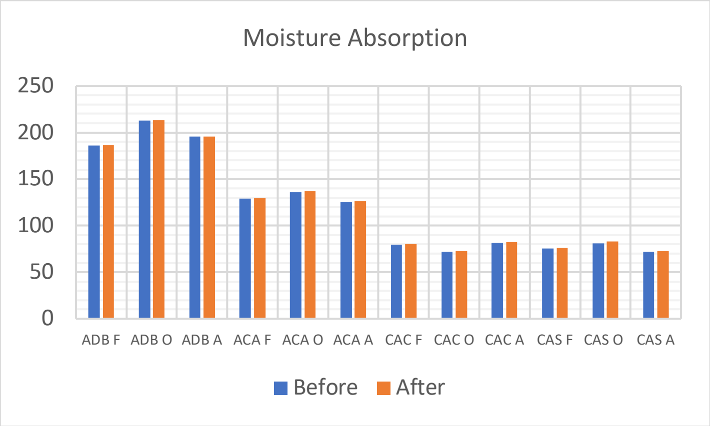
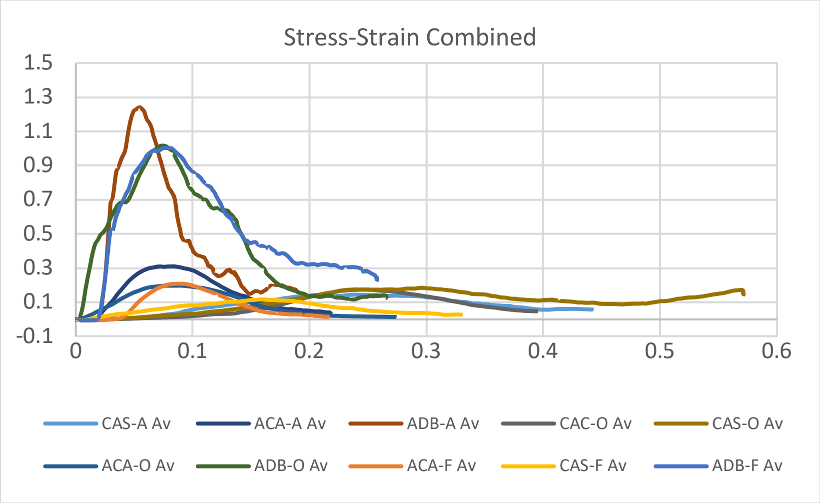


Figure 2 Moisture Absorption Results

4.3 Compression Results

As expected, the ADB blocks were capable of withstanding greater loads, reaching a maximum of 3100N. Figure 3 below compares the stress-strain for each recipe block; the results demonstrate how the ADB bricks are superior to the FWBP composites, with the ACA recipe having the second-best load capacity. Additionally, the CAC and CAS blocks are shown to reach their maximum load at a greater displacement than the more homogenous ADB and ACA, indicating that the space between the particles was greater, before fracturing. This was previously highlighted by the blocks being subject to greater water absorption. This showcases the infringement that the FWBP integrated into composite mixtures, has on the material performance. The method utilised to conduct the compressions tests showed to have its limitations, however, as the materials were incapable of showing their true potential to compare to the target goal 300N/m2, as the aid tents support.



5. Conclusion

This research investigated the potential of utilising FWBP as a resource stream for materialisation. The investigation included an integration of vernacular construction, and novel biocomposite conceptions, to produce a total of five composite recipes. The results identified that the ADB-recipe was the best performing overall, with known benefits in thermal mass, water-retention, and load bearing, proving the hypothesis to be true. However, testing of the FWBP recipes did show potential at a lesser degree. Results indicate that high-moisture environments will accelerate the failure of FWBP-composites, especially untreated, due to greater water absorption, however, also show the potential of insulating qualities that FWBP may possess, foreshadowing truth in the hypothesis made. Overall, the lack of absolute data and critical values achieved by this study highlight the need for additional focus on this matter, as trends do indicate potential in this resource stream. This report may be seen as an introductory investigation into the application of FWBP as a resource stream, when sought-after materials are not available, as in RCS across NWS.

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