FY 2009 Progress Report
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Protective shelter materials for equipment, personnel and rescue structures

Project Team:
Leader: Gwynedd A. Thomas
Team members: 1 Masters student (Vladimir Quinones Silva)
1 PhD student (Houmin Li)
Auburn technician staff
Email: gat0001@auburn.edu Phone: 334-844-5461

Objective:

In the previous sponsored project for FY 2008, a concept was pursued to test the feasibility of a reasonable and logical materials assembly for the protection of exterior aircraft or other vulnerable surfaces from ice formation, wind, blowing sand or falling hailstones as a cover in contact with the aircraft. The cover was designed from a combination of appropriate polymer materials. The same general approach for such a cover could, as a next step, be applied to an emergency shelter for first responders and victim in the event of hurricanes, tornadoes, floods or even terrorist attacks. Our purpose in the research proposed herein is to continue to pursue the initial objectives of our first study and to determine and test a basic design to most effectively perform these and other requirements such as light weight and low storage volume to stow the material in a delivery vehicle. We also propose to design the optimized device for easy deployment (Figure 1.), durability and self-leveling adjustment when placing it over any type or grade of ground. Emphasis will also be placed on biodegradability and "green materials" that will be environmentally neutral when the lifecycle of the product has been passed.

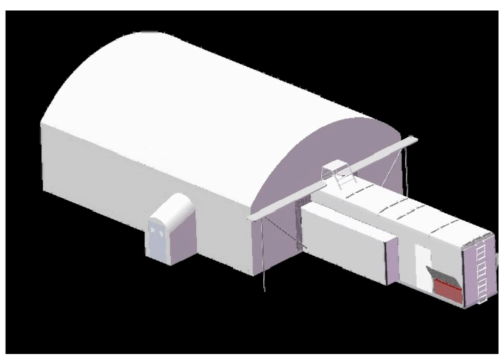

Figure 1. General depiction of a rapid delivery, expandable emergency services shelter

State of the Art:

In an emergency situation such as storms, standard shelters and materials are very susceptible to deterioration and damage from various environmental elements such as (1) sun, (2) heat, (3) thunderstorms, (4) hail, (5) rain, (6) cleaning and disinfectant solvent damage, (7) freezing rain, (8) frost, (9) ice, (10) snow, and (11) extreme cold.
At the present time there does not appear to be any concept, product, application or process that completely or effectively addresses all or most of the safety and environmental hazards that expose emergency workers, first responders, injury victims or displaced families and individuals. There are vendors who sell metal, canvas or woven, coated polymer fiber tents and covers that include variations of standard tent designs, modular tents with flooring, Quonset style flexible structures, and simple shelters based on cargo ship containers with amenities inside for temporary housing. None of these structures are simultaneously light, easy to assemble, durable and contain biodegradable elements.

Proposed solution design:
The bottom layer of the protective cover will consist of a tear-resistant and sterilizable or antiseptic polymer material suitable to serve as a wall structure, be expandable, retain normal heated or air-conditioned atmosphere, and not be a damage prone surface.
The inner layer or layers of the cover could be designed so they have numerous individual air or fiber filled pockets within the structure as shock absorbing and/or temperature insulating layers. The number of rows and layers within will be determined to protect people and objects from wind, temperature extremes, rain, hail or other objects striking it. (Figure 2)

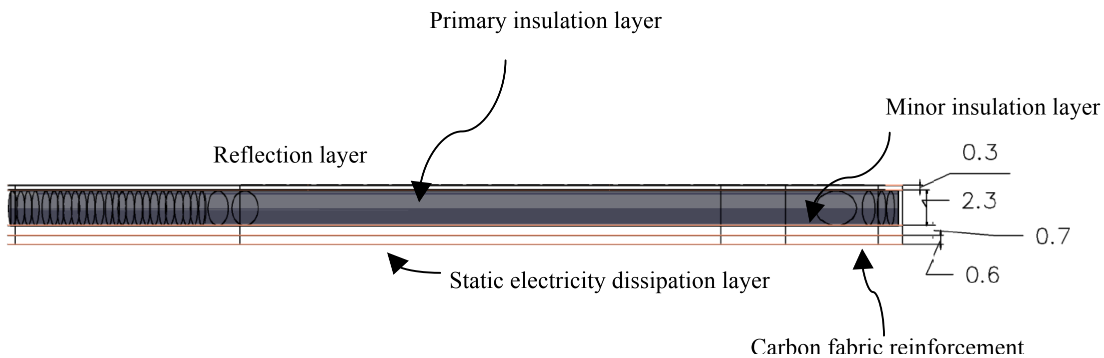

Figure 2. General depiction of multilayer protective cover design

An experimental database already exists at Auburn Polymer and Fiber Engineering to indicate useful designs to protect against environmental hazard damage, so an approximate menu of polymer types, combinations and thicknesses can form the basis for a new, light, portable structure optimized design. Many or all of the tests and results collected for the previous project are fundamentally applicable to the construction of a rapidly deployable, temporary shelter for rescue purposes.
Experiments have been conducted and are still being designed to address critical needs areas of this rapidly deployable shelter concept. To wit, those experiments and results from the researchers respectively responsible for them follow.

Impact Resistance Experimental Methodology (Vladimir Quinones Silva):

The purpose of our new experiment design is to test different configurations and determine from a combination of appropriate polymer materials an order to meet impact resistance requirements. This equipment will help to simulate impacts on materials in a closer approximation to real events.

- Using the low velocity cannon, hailstones with different diameters will be shot towards a polymeric target with specific velocities obtained in previous publications.
- There are two kind of experiments:
  - **Ice impact force measurement** → for observing and measuring the parameters of ice such as diameter, velocity and kinetic energy.
  - **Ice impact on the target** → for measuring the damage or failure of the value of impacting kinetic energy on polymer configuration.
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Test Cabinet
A cabinet of 2 x 0.84 x 0.58 meters was designed with two sections divided by a safety wall composite assembled from contact film, balsa wood and polystyrene foam to prevent ricochet. The first sectional area is where the initial velocity is found using the chronograph, and the second sectional area is where the final velocity is found using a high-speed camera, and impact and deformation measurements are logged.

In the first sectional area, there is a chronograph with three sensors having a spacing of 1' separation. Above each sensor, there is a diffuser that provides a contrast that is illuminated by a 50 Watt halogen lamp. On the opposite side of the lamp there is an aluminum faced panel to provide maximum illumination because the test will be performed in indoor conditions.

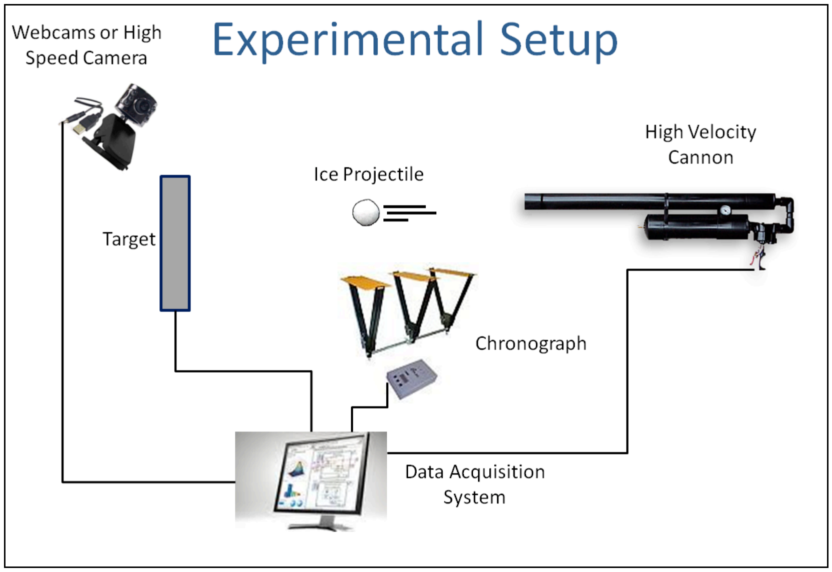

Figure 3. Schematic of the projectile launch device

In the second sectional area, there is an A36 steel frame, manufactured to allow two mounting systems with two angles of incidence (45° and 90°). The force transducer mounting system is aluminum square tubing, which mounts to the base frame; this holds the sensor base for attaching the force transducer. The base frame is attached to the chassis of the test cabinet in a 90° with stainless steel angle bracket, however in 45° set-up, it is attached with A36 steel clamps horizontal spacing of 0.38 m. In addition, there is one 50-Watt halogen lamp to provide appropriate illumination for the high-speed camera. The high-speed camera with a scale will record the impact event, and with this data, the terminal velocity can be determined.
The test cabinet was redesigned with gas shocks to provide unattended open position of the doors for new test set-ups. There are also inspection windows made of Plexiglas that allow quick and easy access during fine-tuning of the equipment and test specimen replacement. There is a sliding door that prevents windblast that may alter recorded velocities. Also if there is a discrepancy with the path of the projectile in the first section this will provide ricochet protection, and it allows access to the changing of barrel diameters.

Frame

At the A36 base frame, which is 349.25 x 349.25 mm and with opening of 266.7 x 266.2 mm, the initial test ice impact force measurement is conducted with a dynamic force transducer (PCB model 200C50) that has a stud where the ice impacts. With this initial set-up the data recorded and observed, ice size, velocity and impact force, will be analyzed and quantified to provide appropriate parameters for the second part experiment.
The second set-up is for material testing which it has a matching frame in dimensional aspect to provide a uniformed compressive force along the perimeter of the material tested in order to prevent rotating, and allows in-plane freedom. On the material, two or three strain gages placed 0 mm, 25.4 mm and 76.2 mm from the center. Therefore, the deformation (strain) will be measured at pre-determined points on the material during impact conditions.

Low Velocity Cannon
The low velocity cannon was made with schedule 40 PVC pipe and reinforced using the braiding machine. Multiples layers of fiberglass were applied over the reservoir. Polyester resin was applied along with resin transfer molding to infuse fiber to resin matrix. With this process, a higher level of safety is achieved. An electro-valve is in line with reservoir and barrel for trigger mechanism, this system uses a solenoid to release pressure through the barrel. The system for aiming incorporates a fixed reservoir and the barrel is minutely adjustable with a screw-type system in order to fine tune accuracy.

Equipment Cabinet
This cabinet is the housing for all electronic data logging components of the experimental set-up, such as the signal conditioner model 482A21, computers, chronograph printer, PC oscilloscope ADC 216. The software installed on the computers for data acquisition is LabVIEW and PicoLog Recorder, and the information collected will be simultaneous recorded for post-analyze. The wires that transmit data to be collected are protected in a flexible wire conduit from test cabinet to equipment cabinet.

Intended Outcome of Experimental Equipment
With this equipment, it is possible to perform two different kinds of tests for either determining the kinetic energy or measuring the failure in polymer materials.

Integrated Communications Media Design (Houmin Li):

During Oct 1, 2009 through Mar 31, 2010, a series of experiments was conducted to test the feasibility of applying flexible antennae to emergency communication systems and developing self-sustainable emergency communication transceiver modules. Specifically, package error rate (PER) measurements were taken to ascertain that flexible antenna and communication module combinations can outperform the regular whip antenna that are standard with the modules. Moreover, development and debugging over the new communication firmware and GUI software was conducted. The results of these measurements show that there is evidence to suggest that the integration of a flexible antenna, communication module, and flexible solar panel could yield a promising solution towards the emergency communications dilemma in a rapidly deployable shelter.

Experimental Procedure
Indoor package error rate experiments with antenna diversity function turned on, shows successful package transmission in the office complex environment. The PER testing program is developed and compiled into a microcontroller firmware, and then downloaded to the pair of SDBC-DK3 software development boards. The GUI is developed to test the short message capability and data transmission capability of the system.

With our firmware, each SDBC-DK3 kit can serve as either a transmitter or receiver, thus a signal generator is not necessary for this experiment and the whole experiment can be performed on AA batteries. Before the PER testing, the flexible antenna was tested with a HP8753C vector network analyzer (VNA) to make sure the resonant frequency of the antenna matches that of the communication module. The transmitter power was set at 20dBm. The intent of the design is such that when the receiver picks up the signal, it sends out ACK signal back to the transmitter, and the PER in percentage can be calculated.

The flexible antenna is designed based on the woven antenna approach from Auburn University's geotextile antenna project, but with different design considerations. The operation frequency band of the antenna is carefully designed to fit the configuration of the communication module, and the TE10 mode and TE20 mode of the antenna are combined to improve antenna performance and introduce diversity of polarization. The transmitter and receiver modules are set to operate at 915 MHz frequency band. The flexible antenna is set as the base station antenna and the whip antenna of the SDBC is set as the antenna for movement.

The data from the indoor test is promising. With a laptop powering the base station and a 4 AA batteries powering the mobile device, the PER remains less than 1% (meaning 99% of the packages are sent and received correctly) within our office complex and suggests the flexible antenna works pretty well under indoor condition, even with walls and other obstacles and multipath losses present.

Intended Outcome of Experiment

The performed experiment was meant to verify the feasibility of combining flexible antennas with communication module and solar power module to form a stand-alone, self-sustainable wireless communication network node. The indoor testing result is promising; outdoor performance testing is planned to evaluate the overall performance of the system in open environments. The antenna performance can be further improved using meander line and slotting techniques, and even arraying the flexible antennas upon request. The bandwidth of the antenna can also be improved to address the broadband networking requirement, and more compatible with the chosen communication module, which is an intrinsic broadband system. The firmware needs further development. A data link layer with multi hopping capability is to be added beyond the current physical layer, thus making the network a multi-layer system. Finally and importantly, flexible solar panels need to be purchased and integrated with the system to evaluate the power saving characteristics.

Outreach to Industry and Target Market:

This project will make use of a start-up operation in the aircraft covers and shelters industry for input, idea validation and purchase of materials and/or fabrication of test designs in the proposed project. We have successfully engaged Natick Soldier Research, Development and Engineering Center, Shelter Technology, Engineering and Fabrication as a party of primary interest in this project and we are already in communication with their Director as point of contact. Further input is being sought from significant user databases such as emergency responders and military users including the United States Army, Navy, Marines and Air Force. Numerous bases and installations exist in the Auburn University area, and visits will be both convenient and inexpensive. Travel to the manufacturer/subcontractor's site would be very beneficial to discuss and plan for the correct design and assembly of samples for testing.