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PRELIMINARY SCALE MODEL SNOWDRIFT STUDIES USING BORAX IN A WIND DUCT

BY

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U. S. NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California 93041

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Y-F015-11-01-025

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ABSTRACT

Camps in areas of drifting snow, such as Antarctica, where there is no depletion of the annual supply quickly become inundated requiring continual digout and eventually movement of the camp. In an effort to alleviate drift problems, preliminary scale model drift studies were conducted in a wind duct using borax as a snow simulator. Models of 64-foot Jamesways were tested in various orientations and group layouts. The effect of elevating these models on snow platforms above the surrounding surface was observed, and tests were conducted on building shapes not commonly used in polar regions. It was concluded that the drift accumulation rate around the type of buildings presently in use can be reduced by orienting them 45 degrees to the wind, and by elevating them above the surrounding surface on snow platforms. It was further concluded that buildings should be constructed with as few corners as practical to reduce the rate of drift accumulation.

The drift pattern around a structure near Byrd Station, Antarctica, oriented 45 degrees to the wind during the winter of 1966 verified the findings for this orientation. Based on the results of the scale model snowdrift studies, two buildings from the NCEL camp near McMurdo were placed on an elevated snow platform and oriented 45 degrees to the wind when they were relocated in December 1966.

Additional scale model drift tests are planned to determine drift accumulation rates over longer periods of time, establish a time scale for models in the wind duct, and study the effect of building area and height upon drift patterns and accumulation rates.

INTRODUCTION

Drifting snow is a particularly critical problem in polar areas because there is no depletion of the yearly supply of perennial polar snow. Any obstruction on the surface causes drift and consequently accelerates the accumulation. Buildings placed on the surface of snowfields quickly become inaccessible and eventually completely buried. The rate at which drift accumulates can be partially controlled by the orientation of a building or the relative positioning of groups of buildings. The drift pattern and rate of accumulation is also influenced by the shape of the building.

Using building models in a wind duct, the effect of building orientation, relative positioning, and shape can be studied on a scale that would take years to accomplish in the field. This technical note presents a series of preliminary tests conducted with building models in a wind duct using borax to simulate snow.

WIND DUCT

The duct[1] used in the scale model tests (Figure 1) is 23-1/2 feet long. It is composed of a 4-foot-long entrance section, four 2- by 2- by 3-foot-long test units, a 4-1/2-foot-long steel fan and enclosure, and a 3-foot-long collection box. The duct is completely metal lined with all sections, except the steel fan enclosure, constructed of 3/4-inch aluminum-faced plywood. The sections are all joined by clips and sealed with gasketing except for the collection and fan sections, which are bolted together.

Air enters the duct through an eliptically curved entrance and passes through a 20-gage steel diffuser with 2- by 2-inch openings 10 inches deep. Material picked up by the wind in the test units passes the fan and is collected in a 36- by 40- by 66-inch box and an 18-inch-diameter, 9-1/2-foot-long tubular heavy-duty canvas bag which is suspended by ties from a rack extending the length of the wind duct.

Air is drawn into the duct by a 32-inch-diameter, 21,000-cfm fan housed in a heavy-gage welded-steel enclosure placed at the end of the test units. A 220-volt, 3-phase, 15-hp, varidrive motor, equipped with heaters and cold-weather lubrication for use to -30°F, varies the fan speed from 500 to 1,600 rpm. The blower drive shaft rpm is measured by an electric tachometer which automatically records on a strip chart.

In order to add material uniformly to the airstream, a vibratory shaker at the duct entrance drops material through an 80-mesh screen into a dispenser with outlets at 4-inch increments.

TEST CONDITIONS

It was planned to test models of the Jamesway shelter in 64-foot lengths, as this 16-foot-wide, semi-circular, arched-rib structure is widely used in polar regions. In order to test the desired layouts and still avoid the influence of the sides of the wind duct, the largest scale to which these buildings could be constructed was 3/32 inch equals 1 foot. Other building shapes tested were constructed to the same scale with floor areas comparable to the 64-foot Jamesway. Although it was impossible to scale the buildings to the borax particle size, it was expected that the test results would be a good indication of drift patterns.

The borax was shaken into the wind duct through an 80-mesh screen, resulting in a maximum particle size of 0.18 mm. Based on a mean snow particle size[2] of 1 mm, the linear scale factor for the borax was 1/5.6. A tunnel speed of 13.5 mph was used. At this speed, the borax particles were just above the fluid threshold velocity.

ORIENTATION AND ARRANGEMENT

In the study or orientation and arrangement of groups of buildings, scale models of 64-foot-long Jamesways were placed on a revolving platform 22 inches in diameter. Borax was added upwind to bring the surface to the same level as the platform, so the models were actually at surface level. Drift stakes, banded to scale at 1-foot intervals, were placed on the platform to give an indication of depths of drift at various locations. The revolving platform permitted rotating the models 90 degrees to observe the effects of both storm and prevailing winds, which are often perpendicular to each other. Tests were conducted by operating the wind duct for 1 hour in the storm wind direction while adding borax, followed by 1/2 hour in the prevailing wind direction with no borax added.

Initial tests with single buildings oriented with the wind at various angles revealed that when a Jamesway is placed at 45 degrees to the storm wind, the ends are blown free of drift. There was also a slower overall accumulation due to the lower profile of the building in the direction of the wind. The borax was carried over the building instead of being deposited on the windward side as when the building axis is perpendicular to the wind direction. When the building axis is parallel with the wind, drift collects rapidly around the downwind end. The 45-degree-angle orientation also has the advantage of remaining the same for both storm and prevailing winds when these winds are perpendicular to each other.

Two buildings were placed at a 90-degree angle to each other to form a "V". The "V" was first oriented with the apex directed downwind from the storm direction (Figure 2). In this case, the area between the buildings acted as a trap, causing the borax to accumulate rapidly, but keeping the area downwind of the buildings free of drift except for a low ridge where the snow was carried between the ends of the buildings. When the platform was turned 90 degrees to simulate prevailing wind, the drift-free areas quickly began to accumulate borax (Figure 3). The buildings were also tested with the apex of the "V" pointing into the storm wind (Figure 4). In this arrangement, the wind tended to be directed around the buildings, leaving the area between buildings relatively drift free. The greatest drift was on the windward sides of the buildings.

Three buildings were placed side by side in the conventional company street arrangement, but oriented with their major axes 45 degrees to the storm wind (Figure 5). Both storm and prevailing wind left the ends of the buildings relatively clear. There was only minor drift between buildings in this arrangement.

Three buildings were placed in a "Y" arrangement, with each building at a 120-degree angle to the adjacent building and one leg of the "Y" directed into the storm wind (Figure 6). The area downwind of the two angled buildings remained relatively drift free similar to the "V" layout; however, there was a rapid accumulation at the center of the area, which was common to all three buildings.

Another 3-building layout was tested in which two buildings were placed at a right angle to each other, and the third was placed on the storm wind side to act as a baffle to divert the wind around the area (Figures 7 and 8). This resulted in a drift-free area between the two buildings, but the upwind building accumulated considerable drift around it.

In the arrangements tested, the company street plan with buildings oriented 45 degrees to the storm wind appeared to offer the best drift control and the most practical arrangement for groups of buildings in any quantity.

ELEVATED PLATFORM

Three Jamesway models were placed in the wind duct with their longitudinal axes parallel to the storm wind. Two of the buildings were placed side by side, and the third was placed downwind and in line with one of the other buildings. The scale of 3/32 inch equals 1 foot was used in these tests, and all dimensions discussed are given in full scale. This arrangement was tested with the buildings at the same level as the surrounding surface, elevated 32 inches ($\frac{1}{4}$-inch model dimension) above the surrounding surface, and elevated 64 inches ($\frac{1}{2}$-inch model dimension) above the surrounding surface. The wind duct was operated for 3 hours until the buildings at surface level were almost completely inundated (Figure 9). Then the buildings were elevated 32 inches and the wind duct was operated for 3 hours. There was slight drifting around the buildings initially, but after the first 15 minutes, there was no change in the drift until the area upwind of the platform had achieved the same elevation as the platform. This required about 2 hours. By the end of 3 hours, the drift between buildings was only 3 to 4 feet deep as compared to 8 to 9 feet deep in the same time with the buildings not elevated (Figure 10). At the end of 5 hours, the drift on the 32-inch platform was comparable to the drift accumulated without the platform in 3 hours (Figure 11). The time difference was the time required for the accumulation on the surrounding area to build up to the level of the platform.

Elevating the buildings on a 64-inch platform had an adverse effect. The turbulence caused by the downward edge of the higher platform caused borax to be deposited at the edge of the platform in such a way to form a berm. Drift in the area of the buildings was accelerated by the influence of the berm and reached a depth comparable to the unelevated situation by the end of 3 hours of operation (Figure 12). This drift accumulation might have been slower if a long ramp were built from the surface to the platform, thus eliminating the abrupt change in elevation which caused the turbulence.

BUILDING SHAPES

Drift patterns were observed around various building shapes not in common use in polar regions. The conventional buildings are rectangular with either a gable or arched roof. The shapes tested at surface level by operating the wind duct for 1 hour in the storm wind direction included hemisphere, cylinder, and hexagon. In addition, the arched-rib type of building was varied from the conventional rectangular floor plan by fitting wedge-shaped sections together in curved plans. These buildings were tested by operating the wind duct for 20 minutes in the storm wind direction.

The hemisphere (Figure 13) and cylinder (Figure 14) produced similar drift patterns. The greatest accumulation was on the windward side; the sides parallel to the wind were swept free of drift; and there was some deposit of drift on the downwind side of the buildings. General accumulation around the hemisphere was at a slower rate than around the cylinder, and the there was a larger area on each side that was swept free of drift. The hexagonal buildings (Figure 15) were free of drift on the downwind side, but were not swept free of drift on the sides parallel to the wind as in the case of the other shapes. The hexagonal shapes were tested with both flat and peaked roofs (Figure 16). There was little difference in the drift around the buildings, but there was less accumulation downwind from the one with the peaked roof.

A building model in the shape of a complete sphere was found to be particularly suited to avoiding drift accumulation. The rate of drift accumulation appears to be proportional to the area of building in contact with the ground or snow surface. Although a spherical building appears impractical for construction and utilization, some study of the effect of base area and building height on drift may be desirable.

The arched-rib sections placed together in curved plans had heavy drift accumulation on the windward side of the buildings just as in the case of the other curved building shapes. There was drift-free area some distance downwind from the buildings; however, there was slight drift against the downwind side of the buildings and a short distance out from the buildings. A layout in a "U" shape resulted in the largest drift-free area downwind from the building.

TIME SCALE

Actual snow accumulation records from the NCEL camp near McMurdo, Antarctica, provide some basis for establishing a time scale for models in the wind duct. The camp consisted of three Jamesways oriented with their major axes parallel to the storm wind, resulting in a situation similar to the test conducted with three scale models at surface level oriented with their axes parallel to the storm wind. The buildings in the camp in Antarctica were essentially buried by the end of 3 years. A similar degree of burial was achieved in the wind duct after 3 hours of operation. Although this one test is not sufficient for establishing a time relationship, more extensive tests and comparison with field data could be used for developing a time scale.

Field records are available over a 4-year period for three Jamesways parallel to the wind direction and a single 28- by 56-foot shop building parallel to the wind direction. In addition, a 1-year record of a single building oriented 45 degrees to the wind in a location where drift is more severe is available.

UTILIZATION

The result achieved in the wind duct by orienting buildings with their major axes 45 degrees to the storm wind was verified at the VLF station near Byrd Station, Antarctica, during the winter of 1966. The buildings in this station consisted of four van-type structures connected together to form a single unit. Because of the particularly critical drift problem in this area, the van-type structures were covered over with 32-foot-diameter corrugated metal arch sections. This shelter, about 100 feet long, included space for fuel bladders and storage, so that all facilities required for the camp were under one roof. The ends of this shelter were enclosed with timber and plywood. The shelter was at surface level at the beginning of the winter, but was badly drifted-in by spring. Although the snow was drifted high on the sides, the ends of the shelter were free of drift and easily accessible.

Based on the results of placing buildings at 45 degrees to the wind in the model studies with borax, this orientation was used for two NCEL buildings at McMurdo, Antarctica, when they were relocated in December 1966. These buildings were a 28- by 56-foot shop with a gabled roof, and a 16- by 64-foot Jamesway used as a parts storage building. In addition to an application of the 45-degree orientation, these buildings were also placed on a 48-inch-high snow platform with a 25 degree slope up to the platform on the windward side. Observations will be made on the drift following storms and on the overall increase in useful life over buildings erected at surface level with the conventional parallel or perpendicular orientation.

FINDINGS

The scale model snowdrift studies using borax in a wind duct indicate:

1. Arched-roof buildings oriented 45 degrees to the wind in areas of drifting snow remained accessible at the ends for one hour in the model studies and for one winter season under actual field conditions.
2. Elevating buildings on snow platforms above the surrounding surface lengthens the useful life of buildings by the time required for the surrounding structure to attain the same level as the platform, except when change in elevation is so abrupt that it causes turbulence which accelerates drift accumulation.
3. Drift accumulates around a cylinder at a faster rate than a hemisphere, and around a hexagonal shape at a faster rate than a cylinder.
4. All curved shapes result in slight drift against the downwind side, but drift-free areas a short distance downwind from the building.

CONCLUSIONS

1. Drift accumulation rate around the type of buildings presently in use in polar regions can be reduced by orienting the buildings 45 degrees to the wind, and by elevating the buildings above the surrounding surface on snow platforms.
2. Buildings should be constructed with as few corners as practical to reduce the rate of accumulation.
3. More extensive testing in the wind duct and additional field observations are required to study the effect of drifting over longer periods of time, determine a time scale for model tests, and study the effect of building size and proportions on drift accumulation rates.

FUTURE PLANS

Additional scale model snowdrift tests are planned:

1. Study of drift accumulation rates around various building shapes and orientations throughout the useful life of the buildings by operating the wind duct for longer periods of time than in the preliminary studies.
2. Comparison of drift accumulation around scale models with field records of actual full-scale accumulation rates in an effort to establish a time scale for models in the wind duct.
3. Study of the effect of area and height of buildings upon drift patterns and accumulation rates.

ACKNOWLEDGEMENTS

The author is indebted to Mr. R. A. Kennedy for setting-up and conducting several of the wind duct tests, and to Mr. W. R. Krout for his excellent assistance during the tests.

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1. U. S. Naval Civil Engineering Laboratory. Technical Note N-682: Snow movement characteristics - Wind duct borax tests, by N. S. Stehle. Port Hueneme, Calif., Dec. 1964.
2. U. S. Army Snow, Ice and Permafrost Research Establishment. Research Report 73: Scale model studies on snow drifting, by Gordon H. Strom, George R. Kelly, Edwin L. Keitz and Robert F. Weiss. Wilmette, Ill., Sep. 1962.

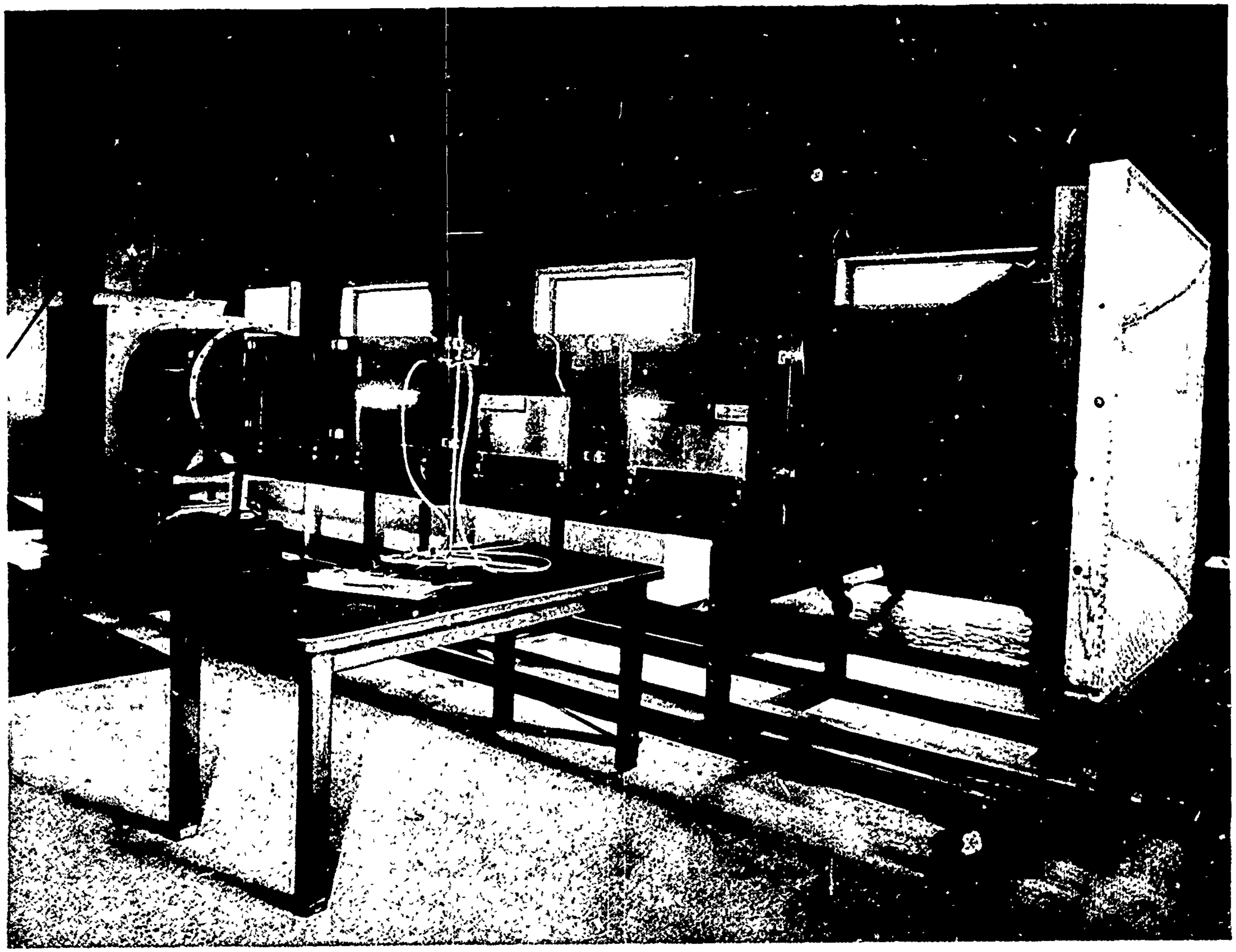

Figure 1. Wind duct used for scale model snowdrift studies.

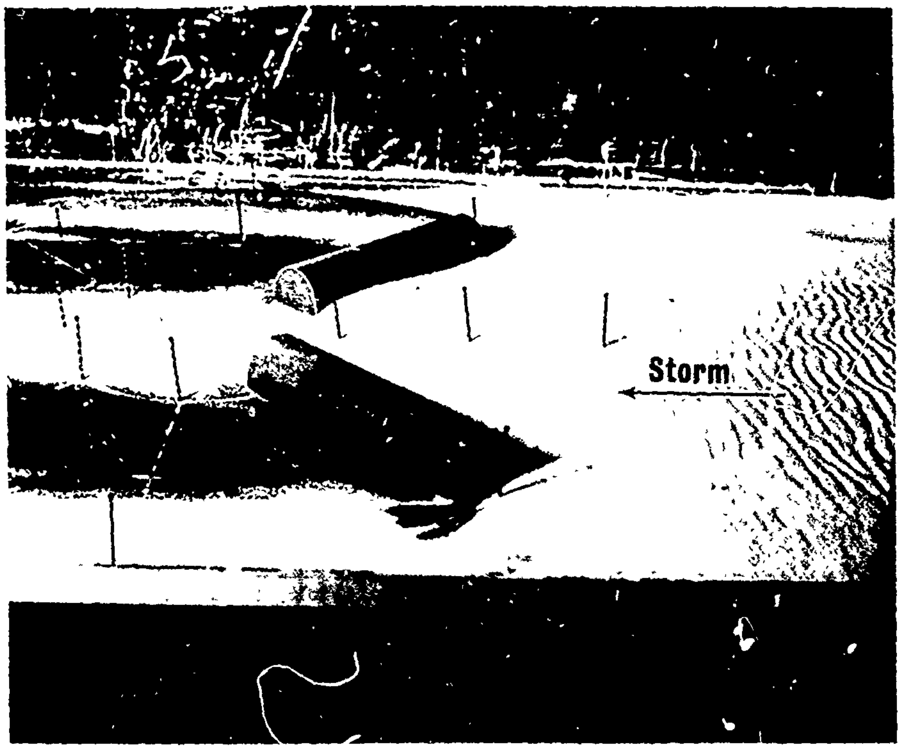

Figure 2. "V" plan after 1-hour storm wind.

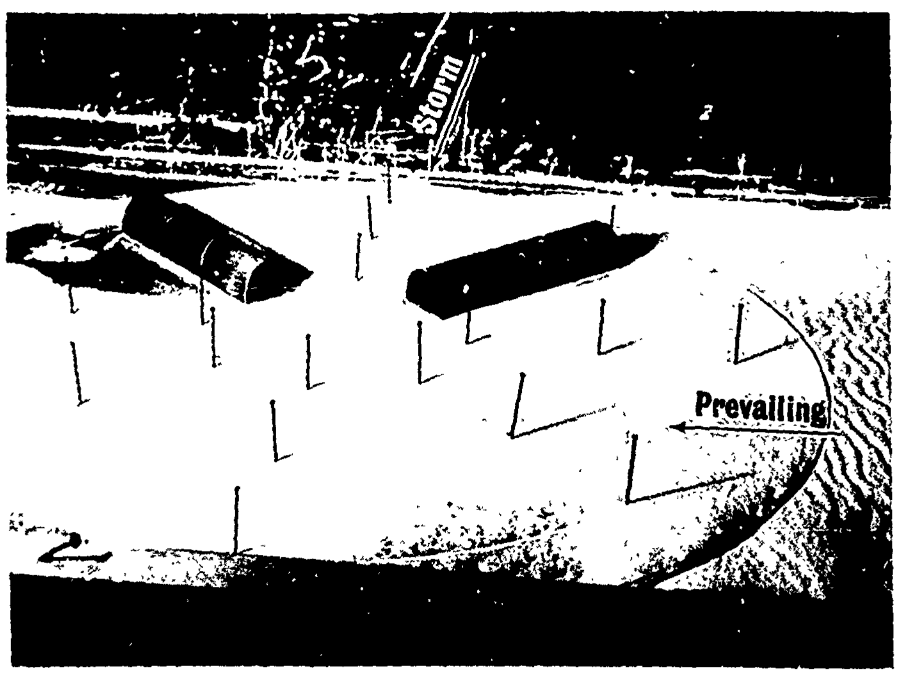

Figure 3. "V" plan after 1-hour storm wind and 1/2-hour prevailing wind.

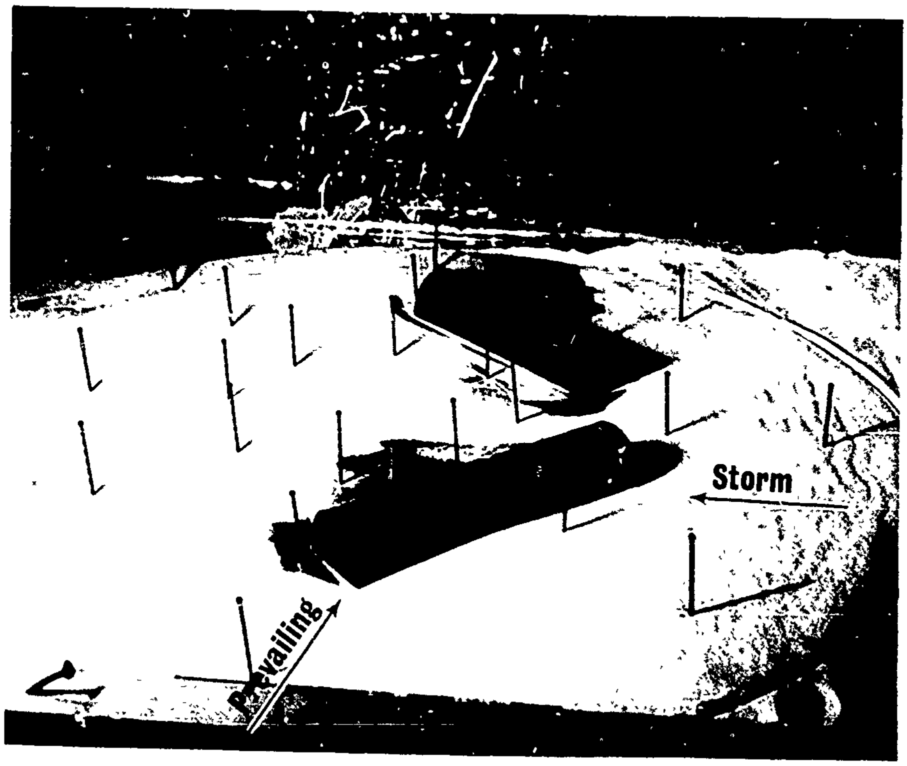

Figure 4. "V" plan after 1-hour storm wind and 1/2-hour prevailing wind.

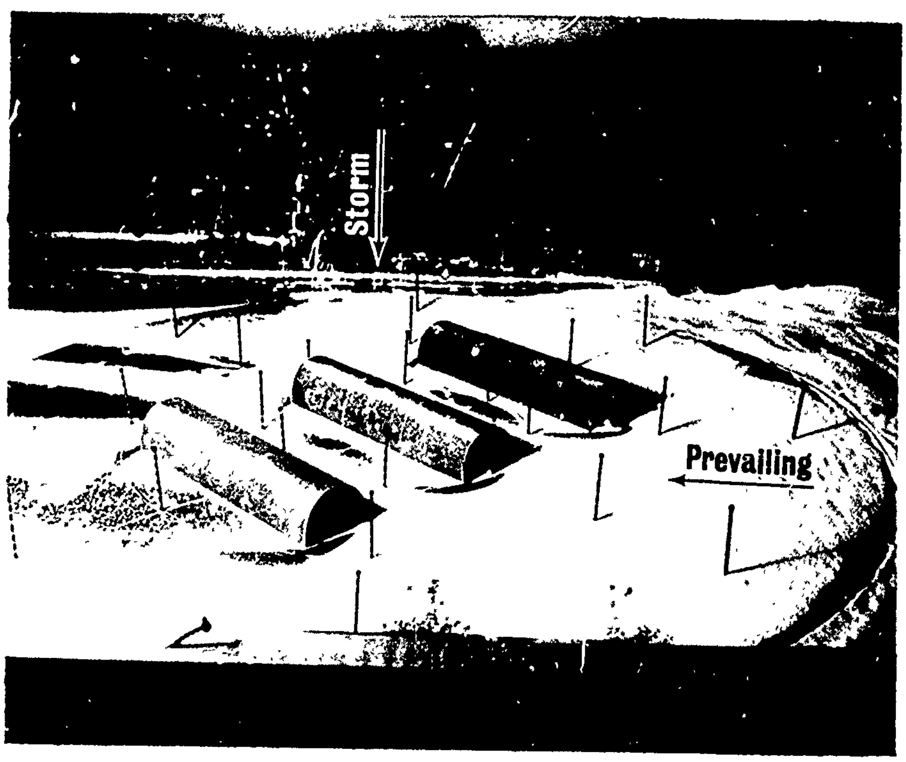

Figure 5. Company street plan with building axes 45 degrees to wind. One-hour storm wind and 1/2-hour prevailing wind.

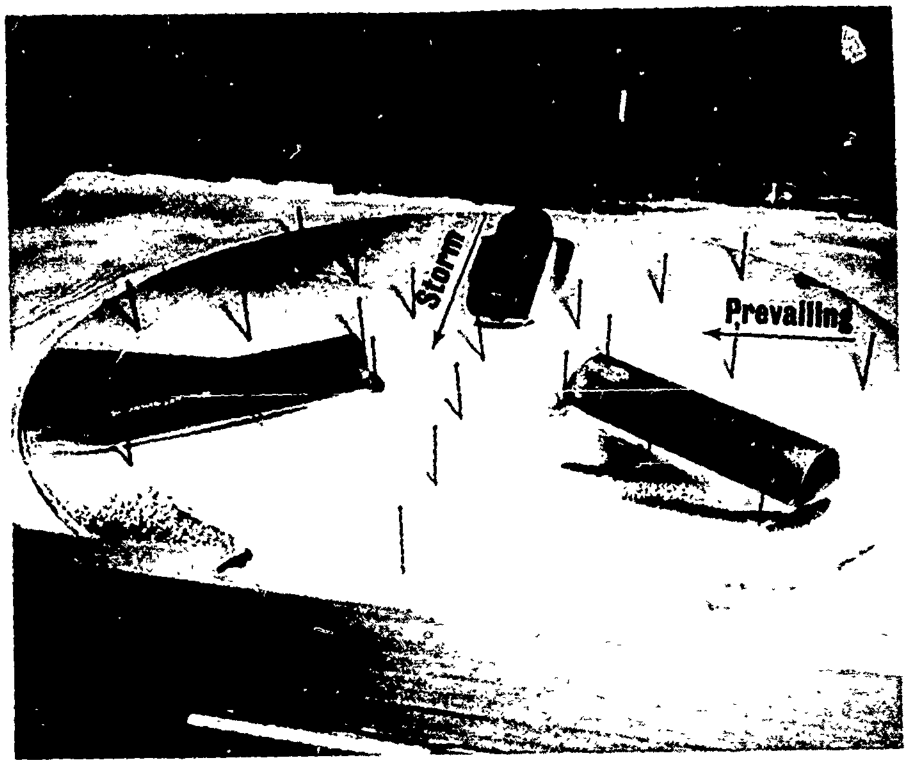

Figure 6. "Y" plan after 1-hour storm wind and 1/2-hour prevailing wind.

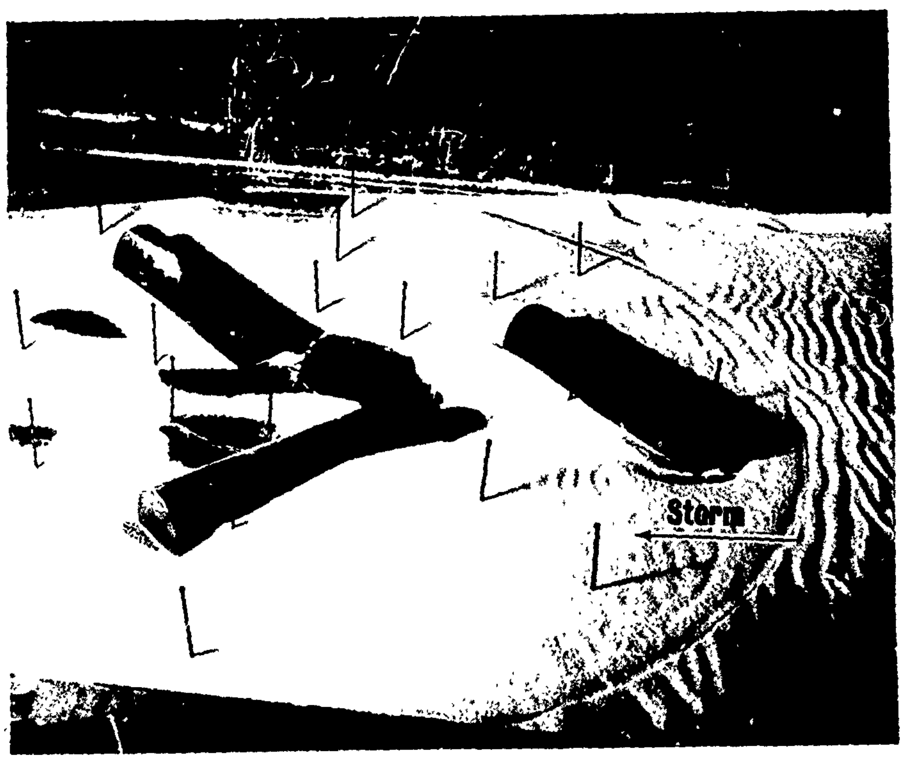

Figure 7. Right-angle plan after 1-hour storm wind.

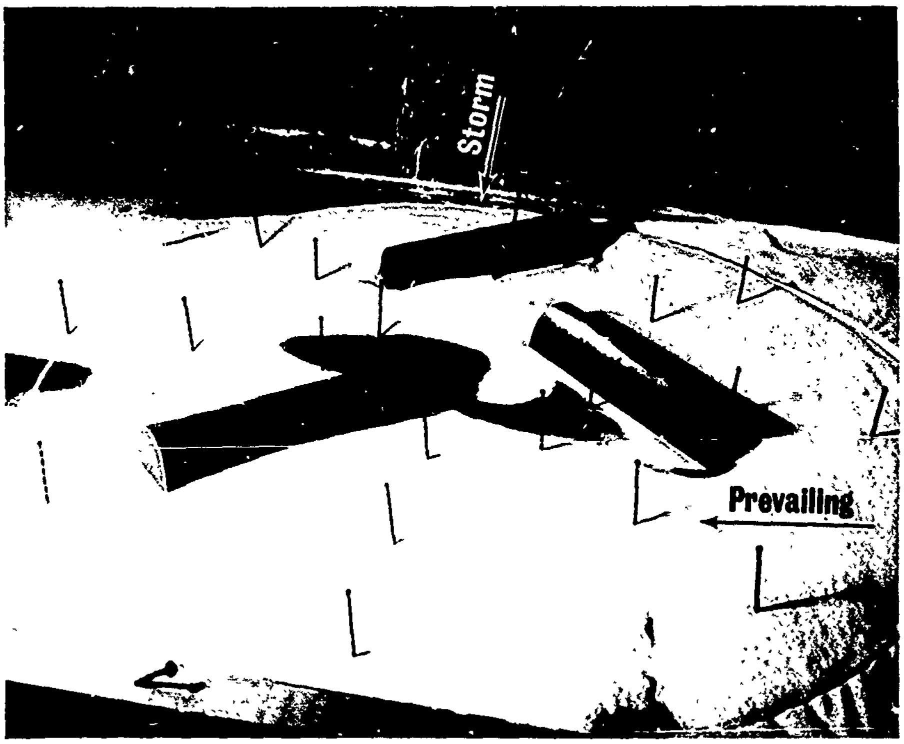

Figure 8. Right-angle plan after 1-hour storm wind and 1/2-hour prevailing wind.

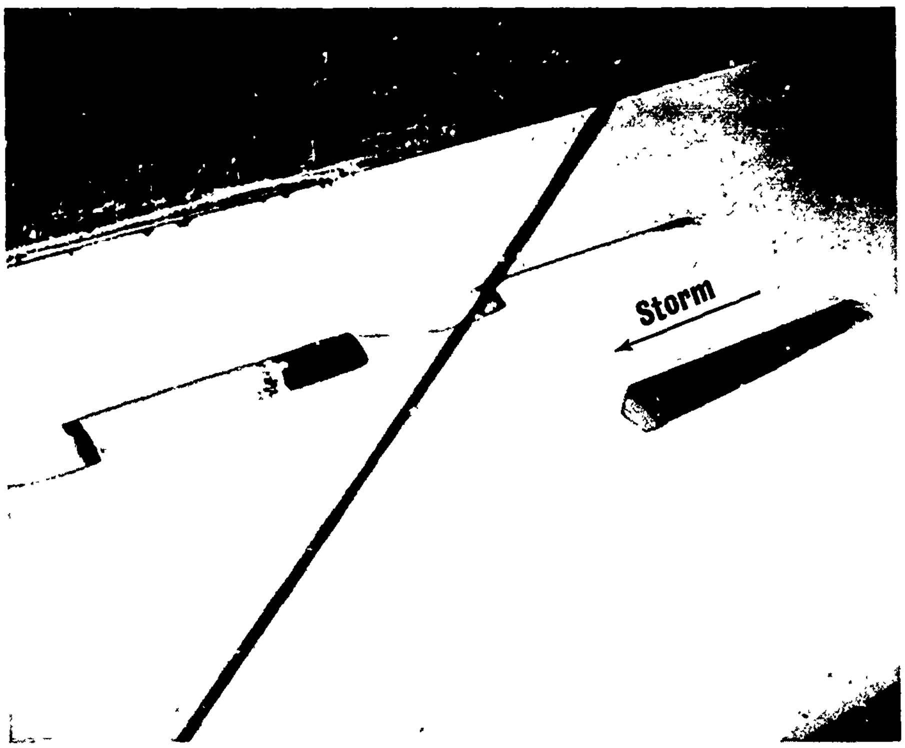

Figure 9. Buildings at surface level after 3-hour storm wind.

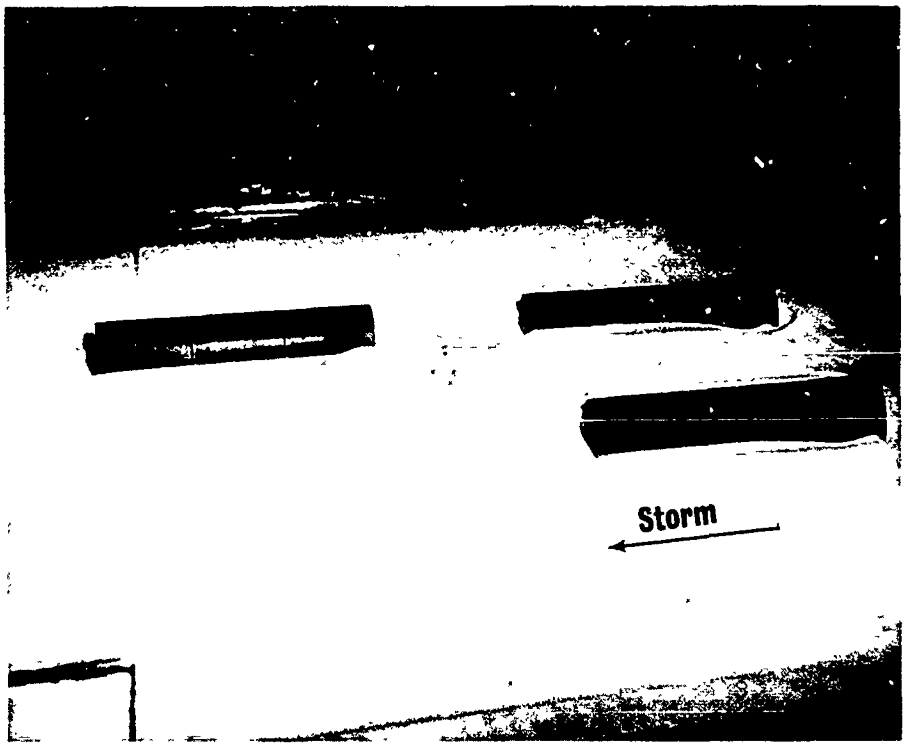

Figure 10. Buildings on 32-inch (1/4-inch model dimension) platform after 3-hour storm wind.

Figure 11. Buildings on 32-inch (1/4-inch model dimension) platform after 5-hour storm wind.

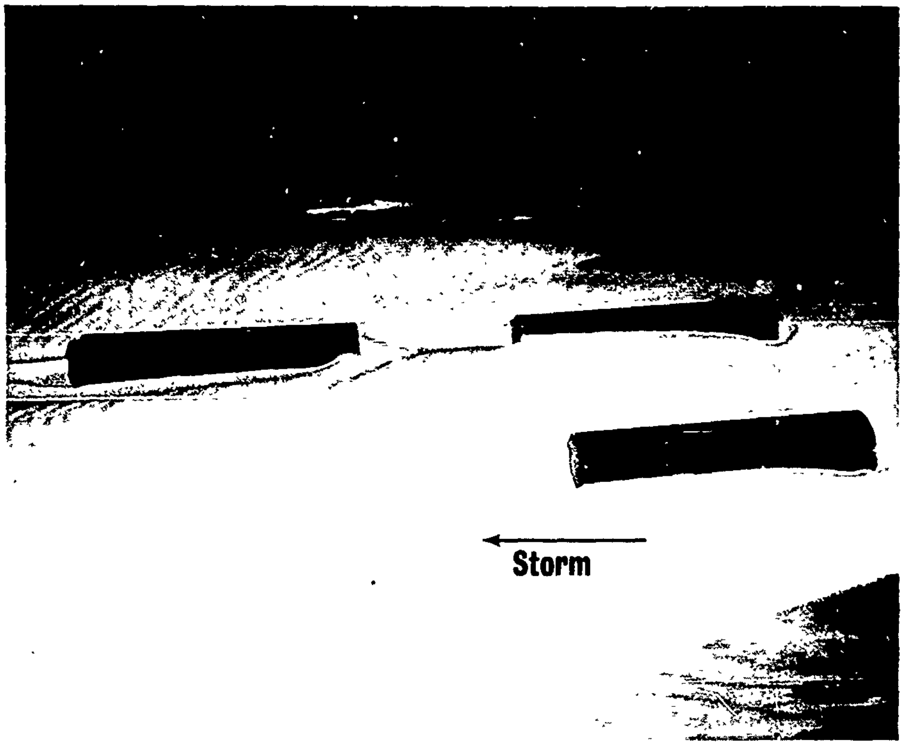

Figure 12. Buildings on 64-inch (1/2-inch model dimension) platform after 3-hour storm wind.

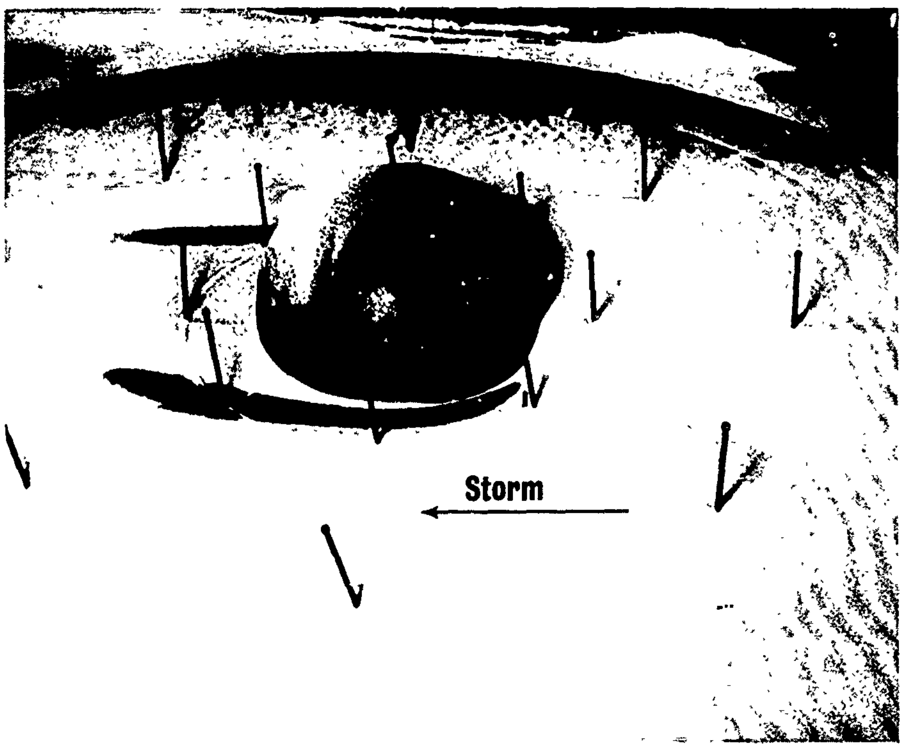

Figure 13. Hemisphere after 1-hour storm wind.

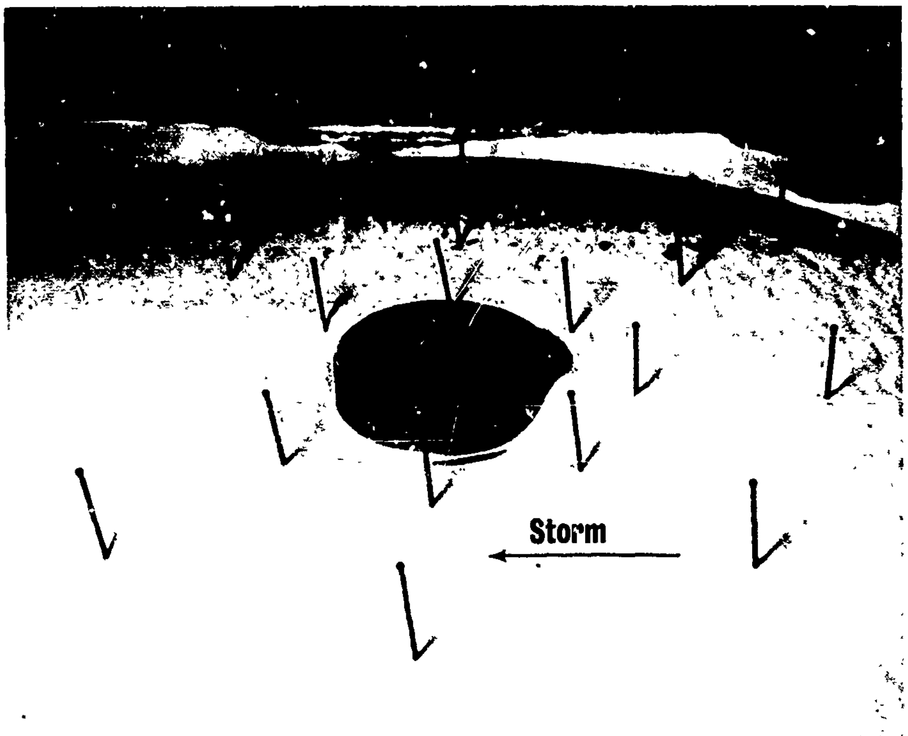

Figure 14. Cylinder after 1-hour storm wind.

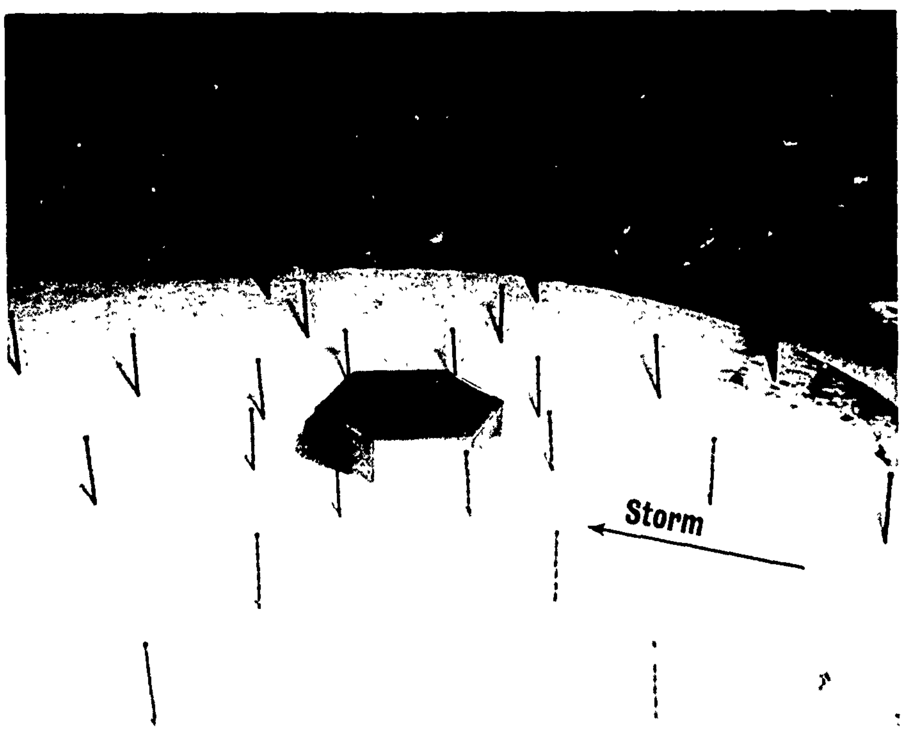

Figure 15. Hexagonal building with flat roof after 1-hour storm wind.

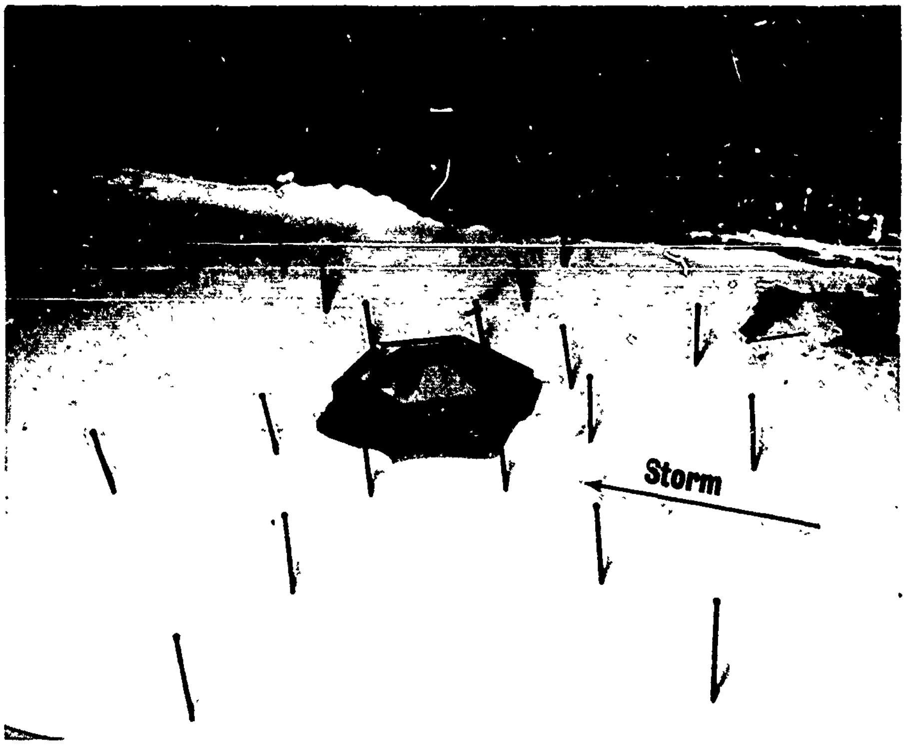

Figure 16. Hexagonal building with peaked roof after 1-hour storm wind.

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