WIND PRESSURE (RAILWAY STRUCTURES) COMMISSION.

TO THE RIGHT HONOURABLE THE PRESIDENT OF THE BOARD OF TRADE

London, May 20th, 1881.

SIR,

IN compliance with the instructions from the Board of Trade (a copy of which is given in the Appendix) to consider the question of wind pressure on railway structures, and to report to them on the subject, we have made such inquiries and procured such information on the subject referred to us as we deemed necessary, and have now the honour to report the conclusions at which we have arrived

It was necessary in the first instance to ascertain as accurately as possible from the sources which were accessible to us what the highest pressures of the wind in this country amount to. With this object we obtained from those observatories and stations where the pressure or velocity of the wind is measured, the statements which we give in the Appendix. In order to exhibit the action of the wind during heavy storms, we have also appended lithographed copies of wind diagrams taken by means of self-registering apparatus at Bidston, Glasgow, and Greenwich.

At some of the stations from which we have obtained returns the wind pressures are measured directly by Osler's self-registering pressure anemometers, at others the velocity only of the wind is measured by Robinson's rotating anemometers, the velocity of the wind being taken at three times the velocity of the revolving cups

For some stations the only published information is the run in miles of the wind during each hour. There can obviously be no more than a general accordance between this and the greatest pressure experienced during the hour To utilize for our purpose observations taken at stations where the velocity only of the wind is recorded, the records of the Bidston Observatory, where both elements are recorded, have been employed as furnishing a means of connexion between the two In the case of high winds, with which alone we have to deal, it was found that the greatest pressure recorded in an hour was tolerably well proportional to the square of the mean velocity during the hour, and that the empirical formula $\frac{V^2}{100} = P$, where $V =$ maximum run in miles of the wind in any one hour and $P =$ maximum pressure in pounds on the square foot at any time during the storm to which V refers, represented very fairly the greatest pressure as deduced from the mean velocity for an hour We have accordingly given in the Appendix a table calculated from the above formula for deducing maximum pressures from observed velocities

In addition to the tables obtained from English, Irish, and Scottish stations, which are those only that are strictly applicable to our inquiry, we give as matter of information a summary of strong winds registered at stations on the Continent and in India.

It will be seen on reference to the Tables that the wind pressures vary greatly at different stations This, no doubt, mainly arises from difference of exposure of the stations to the action of the wind in consequence of the geographical and local circumstances of their position, but may in some cases be partly caused by differences in the instruments used for measurement. Thus at Glasgow the highest recorded pressure per square foot is 47 lbs., while at Bidston near Liverpool the indicated pressure on one occasion amounted to 90 lbs., and on another occasion to 80 lbs.

But the pressures at Bidston seem very abnormal, being much beyond what have been noticed at any of the other stations. The conformation of the ground on which the Bidston Observatory stands is such that the velocity of the wind there might be greatly intensified.

It will be noticed in the lithographs that the records of exceptionally high pressures indicate a very brief duration. From inquiries we have made, we are satisfied that these records are not referable to instrumental error, depending on the recording instrument being carried by its momentum beyond the position of equilibrium under the wind pressure acting at the moment, but represent a real phenomenon But whether the exceptionally high velocities to which such pressures are due extend over a considerable space in a lateral direction, or on the other hand are extremely local, is a point on which we have not been able to find experimental evidence

The differences of the wind pressures observed at different stations led us to consider whether there were any other modes of approximately ascertaining the force of the wind for our purpose There are many buildings, tall chimneys, ship building sheds, &c., which probably would not withstand pressures so extreme as those we refer to, but in most cases the contour of the adjoining ground, and the obstruction to wind by adjoining buildings, trees, and other surrounding objects, would render conclusions drawn from such cases unreliable It occurred, however, to us that some useful information might be drawn from another source, viz from railways themselves

It is obvious that on existing railways that have been long in use, a series of experiments, if we may apply such an expression to them, have for many years been carried on, for over them trains have been running at all times of the day and night on high and unsheltered embankments and along other spaces exposed in many cases to very strong winds

Now, a wind pressure varying from 30 to 40 lbs per square foot, is sufficient to overturn the ordinary Railway Carriages that have been in use during the last 25 or 30 years, and we thought it useful to inquire from the different Railway Companies for cases where railway carriages have been overturned by the force of the wind The only cases of this kind that have been brought to our knowledge are appended to this Report

From the information thus acquired, from the inquiries we have made, and from the consideration we have given to the subject, we are of opinion that the following rules will sufficiently meet the cases referred to us —

(1.) That for railway bridges and viaducts a maximum wind pressure of 56 lbs per square foot should be assumed for the purpose of calculation

(2.) That where the bridge or viaduct is formed of close girders, and the tops of such girders are as high or higher than the top of a train passing over the bridge, the total wind pressure upon such bridge or viaduct should be ascertained by applying the full pressure of 56 lbs per square foot to the entire vertical surface of one main girder only. But if the top of a train passing over the bridge is higher than the tops of the main girders, the total wind pressure upon such bridge or viaduct should be ascertained by applying the full pressure of 56 lbs per square foot to the entire vertical surface from the bottom of the main girders to the top of the train passing over the bridge

(3.) That where the bridge or viaduct is of the lattice form or of open construction, the wind pressure upon the outer or windward girder should be ascertained by applying the full pressure of 56 lbs per square foot, as if the girder were a close girder, from the level of the rails to the top of a train passing over such bridge or viaduct, and by applying in addition the full pressure of 56 lbs per square foot to the ascertained vertical area of surface of the ironwork of the same girder situated below the level of the rails or above the top of a train passing over such bridge or viaduct The wind pressure upon the inner or leeward girder or girders should be ascertained by applying a pressure per square foot to the ascertained vertical area of surface of the ironwork of one girder only situated below the level of the rails or above the top of a train passing over the said bridge or viaduct, according to the following scale, viz —

(a.) If the surface area of the open spaces does not exceed two-thirds of the whole area included within the outline of the girder, the pressure should be taken at 28 lbs. per square foot

(b.) If the surface area of the open spaces lie between two-thirds and three-fourths of the whole area included within the outline of the girder, the pressure should be taken at 42 lbs. per square foot.

(c.) If the surface area of the open spaces be greater than three-fourths of the whole area included within the outline of the girder, the pressure should be taken at the full pressure of 56 lbs. per square foot.

(4.) That the pressure upon arches and the piers of bridges and viaducts should be ascertained as nearly as possible in conformity with the rules above stated.

(5.) That in order to ensure a proper margin of safety for bridges and viaducts in respect of the strains caused by wind pressure, they should be made of sufficient strength to withstand a strain of four times the amount due to the pressure calculated by the foregoing rules. And that, for cases where the tendency of the wind to overturn structures is counteracted by gravity alone, a factor of safety of 2 will be sufficient

With regard to the eighth paragraph of the Report of the Select Committee on the North British Railway (Tay Bridge) Bill, to which you have drawn our attention, we beg to observe that where trains run between girders they will generally be sufficiently protected from the wind, the degree of protection afforded by the girders depending upon the extent to which the girders are open or close, where the girders are so open as to afford insufficient protection, or where trains run, as in some cases they may do, on the tops of girders, we assume that the engineer will provide a sufficient parapet, but we are indisposed to go further into detail on this subject, as it might tend to stereotype modes of construction, which we think is undesirable

In conclusion we beg to point out that the velocity of wind, like that of every other moving body, is more or less retarded by friction, and will be affected therefore by the character of the surfaces over which it has to pass, which may be rough smooth, or irregular. It will follow, therefore, that other things being the same, greater velocities will be attained at higher altitudes than at low ones, the wind at higher altitudes being further removed from retardation by friction

Though we are of opinion that no bridge or viaduct is likely to be built in such a situation as to expose it to wind pressures equal to those which have been occasionally indicated by the disc on the Bidston Observatory, yet even if that were possible, a bridge or viaduct constructed according to the rules we have given would not be subjected to strains nearly equal to its theoretical strength

On the other hand, there will be many structures of small altitude or in sheltered situations which never can be exposed to the wind pressure we have assumed, and where the application of the rules we have given would require modification

Some modification of the rules may also be required in the case of suspension or other bridges of very large span, but such cases will be of rare occurrence, and we recommend that they should be specially considered when they arise

We have the honour to be,

Sir,

Your most obedient servants,

JOHN HAWKSHAW,
W G ARMSTRONG
W H BARLOW
G G STOKES
W YOLLAND

We, the undersigned, concur in the above Report so far as it goes, but we think the following clause should be added, viz —

The evidence before us does not enable us to judge as to the lateral extent of the extremely high pressures occasionally recorded by anemometers, and we think it desirable that experiments should be made to determine this question If the lateral extent of exceptionally heavy gusts should prove to be very small, it would become a question whether some relaxation might not be permitted in the requirements of this Report

W G ARMSTRONG
G. G STOKES