12. Presence of springs under the dam.
13. Undermining.

The following forces tend to increase the pressure:—

14. Increased pressure due to increase in head.
15. Blows on top of dam by ice, and pressure of ice.
16. Blows on top of dam by debris.
17. Increase of pressure on top of dam through friction of water upon a horizontal plane level with crest, such friction being communicated to this horizontal plane by the rushing plane of water during flood times.
18. Any wrong assumption in estimating the pressure, or any improper method of figuring, or mathematical errors.
19. The action of unequal loads.
20. Unknown internal stresses.
21. The action of back-water, vacuum below the dam, or any unknown force.

Thus we have 21 conditions or forces, each one capable of depriving the structure of some of its surplus strength.

By reference to article: "Water Flowing over Crest of Dam," it will be seen how easily the item No. 14 may eliminate a surplus strength of 1; and by reference to articles: "Moving loads," and "Unequal loads," (in last issue), it will be seen how easily the items Nos. 9, 19, and 20 may eliminate a surplus strength of 1; and by reference to article: "Assumed coefficient of friction should decrease as height of dam increases," (in January issue), it will be seen how item No. 11 may affect the surplus strength.

With any of these items, namely, No. 14, No. 9, No. 19, No. 20, or No. 11, capable of eliminating the surplus strength, we have then no provision whatever for any of the others, namely, Nos. 1, 2, 3, 4, 5, 6, 7, 8, 12, 13, 17, 18 or 21, and it must be admitted that this is an altogether unsatisfactory condition of affairs, and that a factor of safety of 2 is entirely inadequate for any structure of this type.

The meaning of the word "factor" is, of course, well understood. Webster gives it as a term, applied to the multiplier or multiplicand, from the multiplication of which proceeds the product. A safety-factor is the multiplier, which, when multiplied by the pressure, gives the strength, or multiplicand. In considering very low safety-factors, however, such as are given to dams, it will be seen that the gist of the matter is not clearly expressed by such a multiplier. A structure with a safety-factor of 3, has three pressure equivalents, one equivalent to take care of the known pressure, and two of unknown loads and imperfections. A structure with a safety-factor of 2, has two pressure equivalents, one to take care of the known pressure, and one to take care of unknown loads and imperfections. A structure with a safety-factor of 1.5, has 1.5 pressure equivalents, 1 to take care of the known pressure, and .5 to take care of unknown loads and imperfections. A structure with a safety-factor of 1, has one pressure equivalent to take care of the pressure, and nothing for unknown loads or imperfections. A structure with a safety-factor of .99 would have no safety at all, although it may have a factor of .99. The usual safety-factor is, in reality, a strength factor, and the actual safety-factor is this strength-factor, less 1.

No special plea is intended in favor of any change in the use of the word "safety-factor," but rather to point out the true value of the different safety-factors, so as to emphasize the enhanced value accruing to a dam through any increase in its safety factor.

Factors of Safety and Margins of Safety.

The Folly of Low Factors of Safety.

Let us assume a case of three dams.

A having $\frac{W}{P} = 1.3 =$ S.S.F. (sliding safety-factor).

B having $\frac{W}{P} = 1.6 =$ S.S.F.

C having $\frac{W}{P} = 1.9 =$ S.S.F.

The area of B would be 23 per cent. greater than A.
" " " C " " 46 " " " " A.

The cost may be assumed to vary with the area.

The surplus strength of A would be $1.3 - 1.0 = .3$.
" " " " B " " $1.6 - 1.0 = .6$.
" " " " C " " $1.9 - 1.0 = .9$.

The probabilities of the maximum pressure ever being less than assumed, are remote, the surplus strength, then, of .3, .6, and .9 is all that we have as a margin of safety; and it will be seen that while B has but 23 per cent. more area than A, it has doubled the margin of safety; that while C has but 46 per cent. more area, it has three times the safety-margin.

Take as other instances dams D, E, and F.

D having $\frac{W}{P} = 1.5$.

E having $\frac{W}{P} = 2.0$.

F having $\frac{W}{P} = 3.0$.

E costs 33 per cent. more than D, but has double the safety-margin.

F costs 100 per cent. more than D, but has four times the safety-margin.

A large safety-factor would seem, then, to be a good investment, since the cost increases in a simple ratio, while the thing of real value, namely, the surplus strength, increases at a much greater ratio.

As a case of buying insurance: with four times the insurance at but double the premium, as with F to D; or three times the insurance at an increase in premium of 46 per cent., as with C to A, most people would prefer F or C.

The margin of safety is the essential feature, and the one in dispute, since the normal strength must equal the pressure, but the excess must take care of that list of 21 items already mentioned.

Any assumption that the total inertia of the structure can exceed the weight multiplied by the coefficient of friction is deceptive, and disaster only can accrue from assuming the total adhesion upon the sub-base to be equal to the shearing strength at any horizontal plane above the line of sub-base.

Some writers advise the use of a low safety-factor against sliding, claiming that the cement deposited upon the sub-strata becomes a part of such strata, and that to be separated from it shearing must take place.

The many records of failures of dams that have slid out of place, such as Austin, Chambly, Columbus, Portman Shoals, Roxbury, Winston, etc., all tend to show that in their individual instances at least, no such unification of the two units, i.e., the structure and the rock sub-base, had ever taken place.

The Austin Dam is an instance wherein the structure moved out just when the flood had reached a point that gave the pressure that theory showed was just sufficient to move it, theory being based upon the weight multiplied by the coefficient of friction of .65.

No shear ever came to the help of the Austin Dam, or with such a powerful force to its aid it would have held its own against the flood.

The material composing a dam, whether it be masonry or concrete, must of necessity differ in resilience and other characteristics from the sub-base.

This decrement of length under pressure and any movement of the structure due to forward movement of the top under pressure or any other cause, at any point above the line of adhesion, may safely be assumed as sufficient to interfere with the unification of the two component parts.

(To be Continued).

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The Pender Nail Works, St. John, N.B., will build another mill at a cost of $25,000.