EXPERIMENTAL INVESTIGATIONS OF EARTH PRESSURE ON WALLS WITH TWO RELIEVING PLATFORMS IN THE CASE OF BREAKING LOADS ON THE BACKFILL

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Quite economical lightweight walls have found wide use of late in the construction of retaining structures. The construction potentialities of the creation of such walls with consideration of the use of precast members are far from exhausted. The skillful use of the properties of the backfill, having internal friction, permits a considerable reduction of the forces acting on the wall.

One of the main methods of creating economical lightweight structures is the use of relieving platforms connected rigidly with the wall. Earlier the author carried out experiments with one relieving platform in order to investigate: 1) the distribution of pressure over the height of the wall as a function of the position and dimensions of the platform under conditions of the effect of a variously distributed load on the backfill surface; 2) distribution of the pressure on the platform as a function of the intensity and location of the load; 3) character of change of the pressure on the wall and platform in the presence of forward movements of the wall; 4) size of the sliding wedge and position of the surface of sliding for walls with platforms; 5) stress of the backfill behind the wall [1].

An analysis of the results showed that the problems of the interaction of such walls with the backfill are rather complex and the existing calculation methods inadequately take into account the effect of many essential factors [2-5].

The author's experiments established that in the case of wall displacements an internal surface of sliding starting from the end of the platform forms in the backfill zone above the platform. The soil particles in the region between the internal sliding surface, wall, and platform are not displaced during movements of the wall and a state of limit equilibrium does not occur in this backfill zone. The position of the internal and external sliding surfaces depends on the width and depth of embedment of the platform. For the same depth of the platform the dimensions of the sliding zone increase with an increase of the platform width. In the backfill located between the platform and the external sliding surface the vertical components of particle displacement are maximum, whereas the horizontal components are relatively small

TABLE 1

Loading steps	Displace. of wall, mm	E, N	E_1, N	E_2, N	E_3, N	r/h	M_{OV}, N·m	Q_1, N/m	Q_2, N/m
No load	0,062	1283 / 1234	167 / 176	276 / 214	840 / 844	0,315 / 0,290	419 / 369	820 / 900	710 / —
1	0,062	1315	159	294	862	0,314	425	820	720
2	0,062	1347	151	304	892	0,308	428	820	720
3	0,064	1451	186	341	924	0,325	488	860	750
4	0,070	1596	294	344	958	0,358	588	1130	760
5	0,075	1741 / 1691	438 / 425	348 / 250	955 / 1016	0,400 / 0,359	720 / 618	1280 / 1630	760 / —
6	0,077	1875	429	378	1068	0,385	747	1330	770
7	0,081	1952	450	396	1106	0,389	780	1390	770
8	0,088	2134	505	451	1178	0,395	867	1550	800
9	0,092	2370	690	468	1212	0,422	1034	1870	840
10	0,096	2543 / 2589	870 / 889	460 / 328	1213 / 1372	0,455 / 0,416	119,9 / 1107	2040 / 3020	850 / —

TABLE 2

Wall movements mm	E, N	E_1, N	E_2, N	E_3, N	r/h	M_{OV}, N·m	Q_1, N/m	Q_2, N/m
0,096	2543	870	460	1213	0,455	1199	2040	850
0,146	2472	845	471	1156	0,458	1173	2090	880
0,234	2394	892	416	1086	0,475	1175	2240	870
0,42	2466	962	448	1056	0,485	1239	2400	880
0,78	2465	1020	427	1018	0,497	1269	2520	870
1,60	2393	1060	412	921	0,522	1279	2580	870
4,58	2387	1098	409	880	0,531	1306	2790	880
9,62	2480	1176	345	959	0,527	1344	3170	850
19,6	2581	1254	293	1034	0,520	1386	3250	810

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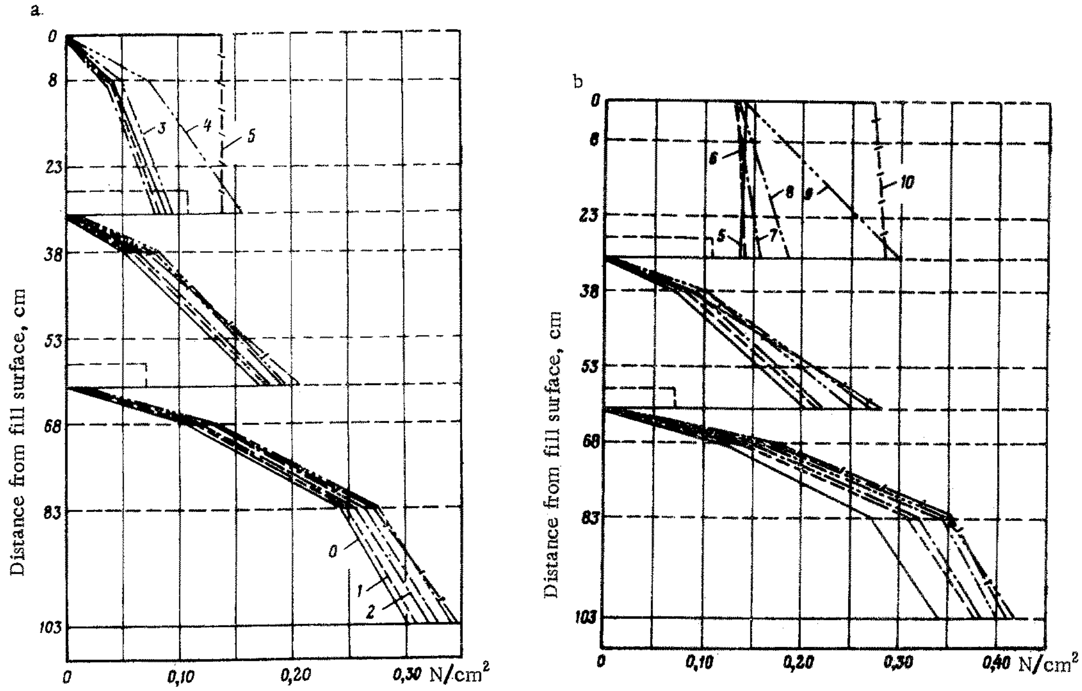

Fig. 1. Diagrams of pressure on wall for different loads on the fill surface. a) 1-5th loading step; b) 6-10th loading step. The numbers of the line correspond to the numbers of the loading step; line 0 corresponds to the case when only sand was filled and the load was not applied.

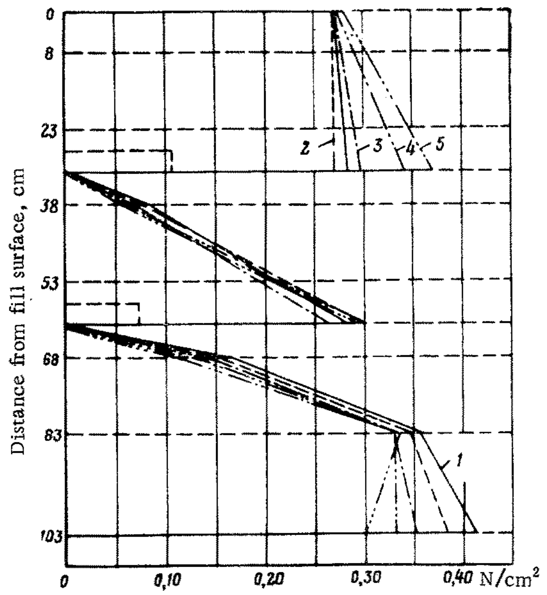

Fig. 2. Diagram of the pressure on the wall during forward movements. 1) After placing the 10th loading step (displacement 0.096 mm); 2-5) during movements equal respectively to 0.146, 0.234, 0.42, and 0.78 mm.

(about twofold less than for particles located below the platform). The intensity of the vertical pressure here during movements of the wall is considerably less than the weight of the overlying backfill and load [6, 7].

The vertical stresses in the region of the backfill under the platform are considerably less than follows from the existing calculation method.

The vertical stresses from the load are distributed at an angle considerably less than the angle of failure reckoned from the horizontal. The load beyond the sliding wedge causes an increase of pressure on the wall. The diagram of pressures on the portion of the wall below the platform has a gradual character. The pressure on the wall below the platform is greater and near the bottom of the wall less than the calculated.

During movements the resultant of the pressure on the lower part of the wall decreases continuously until the displacements equal 1/200-1/100 of the wall height. The minimum pressure on this part of the wall during movements can be severalfold less than the corresponding pressure before the start of displacement. With a further increase of movements the pressure can increase somewhat, not exceeding, however, the pressure before the start of displacement.

For certain relations of the width and depth of the platform the pressure on the upper part of the wall increases during movements, the relative increase of pressure being greater the wider the platform and smaller its depth.

TABLE 3

No. of cell	Channel filled with sand	Stresses at loading steps									
		1	2	3	4	5	6	7	8	9	10
1	0,64	0,66	0,66	0,68	0,75	0,75	0,72	0,74	0,82	0,88	0,89
2	0,16	0,17	0,17	0,16	0,18	0,18	0,18	0,18	0,19	0,18	0,18
3	0,32	0,33	0,34	0,34	0,36	0,36	0,38	0,38	0,40	0,42	0,42
4	0,46	0,46	0,48	0,48	0,49	0,49	0,51	0,51	0,54	0,55	0,55
5	0,58	0,60	0,61	0,60	0,64	0,65	0,66	0,67	0,71	0,72	0,74

TABLE 4

No. of cell	Stresses during wall movements, mm								
	0,096	0,146	0,234	0,42	0,78	1,60	4,58	9,62	19,6
1	0,89	0,90	0,90	0,87	0,83	0,72	0,60	0,68	0,73
2	0,18	0,19	0,17	0,17	0,16	0,15	0,15	0,15	0,19
3	0,42	0,42	0,41	0,40	0,39	0,38	0,39	0,43	0,48
4	0,55	0,55	0,53	0,49	0,46	0,44	0,38	0,58	0,69
5	0,74	0,72	0,70	0,69	0,66	0,63	0,62	0,69	0,78

Prior to the start of wall movements the magnitude of the resultant of the pressure on the platform is less than the calculated pressure, defined as the weight of the overlying backfill and load. During displacement the resultant of the pressure on the platform increases noticeably and approaches the calculated value. These qualitative characteristics are observed also in walls with two relieving platforms.

The investigations were carried out in an open channel of width b = 100 cm, height H = 109 cm, and length l = 177 cm. The face of the model of the wall consisted of 10 × 10-cm blocks bolted to a metal frame of No. 20 H beams. The mass of this panel was about 400 kg. The width of the upper platform was 21.8 cm and of the lower 14.5 cm. The depth of embedment of the upper face of the platforms was respectively 27.3 and 57.3 cm.

The platforms were made of a 4-cm-thick board and were bolted over their length to four brackets welded from 45 × 45-mm angle irons. The brackets in turn were bolted to the wall. Sufficiently rigid attachment of the platform to the quite rigid wall was attained thereby. The surface of the blocks of the wall facing the backfill was smeared with glue and dusted with sand to create roughness.

The pressure on the wall and platform was measured by 12 pressure cells placed along the axis of the wall. The cells were placed on the vertical wall at a depth of 8, 23, 38, 53, 68, 83, and 103 cm. The other five cells measured the vertical pressure on the platforms (three cells on the upper and two on the lower platform).

After filling the channel with Lyubertsy fine quartz sand (unit weight 1.52 tons/m^3, angle of internal friction 33°30') two rows of iron castings were placed on the surface of the fill over the entire length of the channel to provide the necessary load. At first the first row of casting was placed as five steps, which provided a load intensity of 3320 N/m^2 (the distance from the wall to the front face of the load in the 1-5th steps was respectively 82.5, 59.1, 36.8, 14.2, and 0 cm; the length of the loading section in the first step was 88.1 cm), and then the second row with a load of 6420 N/m^2 was applied in the same sequence on the steps of the first row.

The experimental diagrams of the earth pressure on the wall obtained after filling the channel with sand and during application of the 1-5th steps of the load are shown in Fig. 1a.

Similar diagrams obtained during placement of the second loading row (6-10th steps) with an intensity of 3320 + 6420 = 9740 N/m^2 are shown in Fig. 1b, which shows for comparison the diagram obtained after placing the fifth step corresponding to a uniformly distributed load with an intensity of 3320 N/m^2 starting from the wall and located over the entire surface of the fill.

The forward displacement of the wall resulting from deformation of the supporting elements after placing the 10th step was 0.096 mm (diagram 10 in Fig. 1b).

After loading the wall of the model a special forward displacement was imparted by turning the supporting bars. Four diagrams obtained during such movements and corresponding to displacements of 0.146, 0.234, 0.420, and 0.78 mm are shown in Fig. 2 (here and henceforth the magnitudes of movements are indicated from the initial position of the wall before filling the channel with sand).

The data from analyzing the diagrams are presented in Tables 1 and 2, where E is the resultant of the horizontal pressure on the entire wall; E_1, E_2, E_3 are the same on the upper part of the wall with a height of 31.3 cm (above the lower face of the upper platform), on the middle part with a height of 30 cm, and on the lower part with a height of 41.7 cm (from the bottom of the second platform from the top); M_{ov} is the overturning moment of force E relative to the bottom of the diagram. The ratio r/h characterizes the location of the resultant E with respect to the height of the wall, where r is the distance from the bottom of the diagram to the line of action of force E; h = 103 cm is the height of the wall within which the diagram was constructed. Also shown there are the values of the resultants Q_1 and Q_2 of the pressure on the upper and

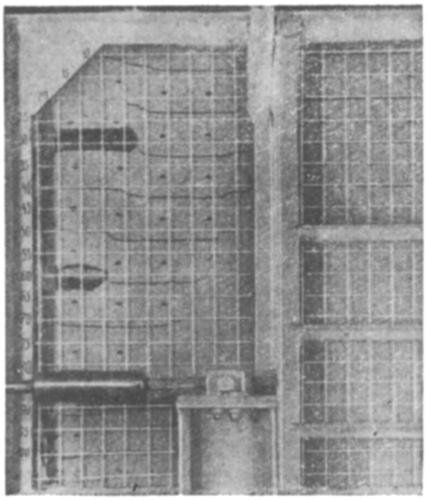

Fig. 3. Displacement of the fill after forward movement of the wall by 19.6 mm.

lower platforms in N/m^2 of the platform length, as well as the magnitudes of the forward displacements of the wall during its loading and movements.

In Table 1 the denominator presents the corresponding values calculated by the presently used Coulomb method of determining the pressure on walls with platforms for q = 0.3320 and 9740 N/m^2 (for an angle of wall friction $\delta = 22°20'$).

We see from Tables 1 and 2 that the experimental resultant E in all cases is close to the calculated. The value of E changes insignificantly during wall movements. The resultant of pressure E_1 during loading of the wall differs little from the calculated; however, during wall movements the value of E_1 increases considerably (up to 1.5 times). The experimental E_2 during loading of the wall is noticeably greater than the calculated. During movements of the wall to 4.5 mm E_2 decreases somewhat, exceeding considerably the calculated nonetheless.

The resultant E_3 during loading is slightly less than the calculated and it decreases even more during wall movements. The minimum of E_3 amounts to less than two-thirds of the calculated.

The point of application of the resultant E during loading and especially during wall movements is higher than the calculated. Therefore, the experimental value of M_{OV} from force E is greater than the calculated moment. Thus, although the total horizontal pressure on the wall is close to the calculated, the distribution of pressure over the height of the wall differs from the calculated.

The resultant of pressure Q_1 during loading is less than the calculated, defined as the weight of the overlying fill and load. However, during wall movements the experimental Q_1 approaches the calculated.

The resultant Q_2 during wall movements changes little. The diagrams of the pressure on the platforms have a pronounced trapezoidal character with the smaller ordinate near the wall. For the upper platform the ratio of the extreme ordinates during loading of the wall is about 2, but during movements increases to 4.

Figure 3 shows the displacement of the fill particles during forward movement of the wall. In this case regions are formed above both platforms within which the fill does not pass into a state of limit equilibrium.

In addition to the 12 contact pressure cells, five soil pressure cells that measured the vertical stresses were placed in the backfill behind the wall. Cell No. 1 was located at the level of the upper face of the lower platform at a distance of 18.6 cm from the wall; cells Nos. 2 and 3 at a depth of 9.5 cm from the bottom of the lower platform at a distance of 4.5 and 11 cm from the wall; cells Nos. 4 and 5 were placed at the same such distance from the wall at a depth of 26.9 cm from the bottom of the lower platform. The results of measuring the stresses in the fill are presented in Tables 3 and 4 (in N/cm^2).

During wall movements the pressure on cell No. 1 decreased by about 30% as a consequence of arching, and only after cave-in of the fill upon displacement of 0.004 H it began to increase, not reaching however the initial value. The load had little effect on cells Nos. 2 and 4 located near the wall. During movement of the wall to 0.004 H the vertical stresses at these points decreased by 20-30%. The stresses on cells Nos. 2 and 4 also decreased slightly for this same amount of movement.

On the whole the experiments revealed rather completely the pattern of the change of contact pressures on the wall and platforms and yielded some data in the complex and little-studied area of experimental investigations pertaining to measurement of stresses in backfill.

The results obtained confirm the need to use more accurate calculation methods in design practice [3, 5], which permits improving the economic indices of using quite promising lightweight walls with relieving platforms.

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