TABLE 3

Statistical Analysis of Typical Concrete Compressive Test Results

(All concrete compressive strengths are expressed in lb/in²)

Mix type	*Spec. comp. strgth f'c* (lb/in²)	*Spec. prob. of exceeding f'c* (%)	*No. of tests*	*No. of 3-monthly prod. periods incl. in analysis*	*Mean value* (lb/in²)	*Std. deviation Population*	*Std. deviation Within test*	*Coefficient of variation Population*	*Coefficient of variation Within test*	*Exceeding f'c* (%)	*Strength exceeded by 90%*	*95%*	*97.5%*
Mass, interior	2,000 at 28 days	90	199	13	3,222	515	177	16.0	5.5	99	2,549		
Mass, exterior, and reinforced structural concrete	3,500 at 28 days	95	866	15	4,963	591	208	12.0	4.2	99		3,975	
Exposed surfaces subject to water abrasion	4,000 at 28 days	95	424	14	5,611	729	221	13.0	4.0	99		4,391	
High-strength grade for prestressed precast concrete penstocks	5,000 at 7 days	97.5	310	8	6,049	454	253	7.5	4.2	99			5,160

TABLE 4

Production Costs for Typical Concrete Mixes

Costs include all plant erection and dismantling costs and all normal project overhead charges. All cost figures are in £/yd³ of concrete produced.

Mix type	*Specified strength* (lb/in²)	*Maximum aggregate size* (in)	*Materials, cost at batching plant* — *Cement* (£/yd³)	*Aggregate* (£/yd³)	*Additives* (£/yd³)	*Batching plant (establishment, removal, & operation)* (£/yd³)	*Testing (investigations, trial mixes, and routine tests)* (£/yd³)	*Total cost* (£/yd³C)
Mass, interior	2,000 at 28 days	6	1.10	0.71	0.033	0.96	0.126	2.93
Mass, exterior	3,500 at 28 days	6	1.63	0.71	0.046	0.96	0.126	3.47
Exposed surfaces subject to water abrasion	4,000 at 28 days	1½	2.45	0.74	0.059	0.96	0.126	4.34

A statistical analysis of the concrete compressive test results, given in Table 3, shows a good standard of control for the main central concrete plant and a high standard of control for the small concrete plant supplying high-strength concrete for the prestressed precast concrete penstocks. The difference in the standard of control in the two cases is because the small plant was essentially a "personal" plant as compared with the central plant which was essentially a "production" plant. The small plant was required to produce only two batch types, it had ample capacity to cope with the demand, and the technician could personally check all phases of batching and mixing. Further, because of the importance of quality in the concrete penstocks, the technician had instructions to reject any concrete batch if for any reason the quality was in doubt.

3.3. Concrete Production Costs

The production costs for typical concrete mixes are given in Table 4. The figures given are the cost of the concrete mix in the concreting bucket, but do not include the cost of transportation and placing. In the separate items allowance has been made for plant installation and removal, and all normal project overhead charges are included.

4. CONCLUSIONS

With the type of cement, the excellence of the aggregates, the use of additives, and a standard of concrete mix control, good quality and consistent concrete was produced at an economic price. By reducing the cement content to a low level the temperature rise due to hydration of the cement was minimised and the normal problems associated with the post-cooling of mass concrete were avoided.

5. ACKNOWLEDGMENTS

The writer thanks the Commissioner of Works for permission to present this paper, and thanks W. E. Sisson of the Ministry of Works for his advice and criticisms.

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Earthmoving for Benmore Earth Dam

T. STORY*
B.E., (MEMBER)

1. INTRODUCTION

THE Benmore earth dam was constructed at the downstream end of the upper gorge of the Waitaki River, 60 miles from the mouth of the river. Crest height was reached in May, 1964, three years and nine months after the main construction of the earth dam began.

The crest of the rolled earth dam is 2,700 ft long, and the maximum height is 360 ft. The upstream and downstream shoulders are built from sandy gravels, the core from clayey gravels. The total measured volume is 15,300,000 yd³.

The Ministry of Works designed and built the structure; about a third of the plant used was hired from New Zealand contractors.

2. GENERAL

2.1. Climate

The climate is good for earthmoving. Rain averages 15 in distributed evenly throughout the year. Three months of drought are common. However, in 1961 and 1962 rainfall reached 21 in and in 1963, 17 in; 1964 was a drier year.

Winter frosts can cause losses of up to half the available working time.

Summer brings very strong winds at times. Mid-afternoon temperatures in December and January often exceed 85° F. Apart from these minor difficulties, conditions throughout spring, summer and autumn are very good.

However, despite the favourable climate, time lost because of weather and its effects amounted to 25% on placing the core and 10% on placing the shoulders.

Major earthmoving machines were offered, on an average, 2,000 hours of work a year.

2.2. Construction Planning

2.2.1. *General*

The first stage of planning was completed in 1957 when the *Benmore Construction Report* (1) was issued. This said: "Fill materials of the earth dam approach 18 million cubic yards. In comparison, no other earth dam done by Ministry of Works has exceeded half a million cubic yards. Construction programme has been based on construction in 400 to 450 days or three seasons' work. This will require placing rates in excess of 700,000 cubic yards a working month and working two shifts in suitable weather. Nothing like this has previously been attempted in New Zealand though it has sound precedent in the U.S.A. . . . Only the development of high speed rubber tyred tractor has made this possible."

It was obvious that large numbers of rubber tyred earthmoving machines would be needed, and the report compared various types of machines: scrapers, end-dump wagons, bottom-dump wagons, their associated pusher dozers, and face shovels. In particular numbers, capital investment (mostly overseas funds), and likely working methods were compared.

2.2.2. *Method of Construction*

One of the most important decisions made in 1957 and later confirmed was: "That the dam should be constructed by the use of direct labour, augmented by contractors' manpower and equipment as required. It was considered that this system gave flexibility and would make the best use of the existing resources within the country." (2) Flexibility and good use of resources were certainly achieved. At times the resources of the Ministry of Works and of the contractors were stretched to the limit.

2.2.3. *Machinery*

Four 4 yd³ excavators—with face-shovel, drag-line, and crane rigs—arrived from the U.S. in the latter part of 1958. These were closely followed by 14 yd³ end-dump wagons and rotary-percussion air-track rock drills. Two excavators were used as cranes on the diversion culverts. The other two were used as face shovels for loading rock from the foundation excavations into the end-dump wagons.

Investigations of materials and machines, and estimation of production continued until the end of 1959. Orders for motor scrapers, end-dump wagons, and crawler tractors were placed early in 1960, and deliveries were completed early in 1961.

2.3. Site

The site is shown on the front cover. The dam spans the downstream end of the upper gorge of the Waitaki River. Areas F and E are the large basins, respectively 6,000 ft upstream and downstream from the site, which provided the gravels for the shoulders. The clayey gravels for the core came from a borrow area further downstream, about 18,500 ft away.

The open site greatly facilitated the moving of all materials round the job. The haulroads and access ramps on the dam were laid out and graded to suit the machines first and the site secondly.

2.4. Roads

2.4.1. *General*

The readily-available gravel deposits were most suitable for building roads. The roads were formed, rolled, and finished with a rock running course. Unweathered blue argillite rock from foundation ex-

*Senior engineer, Ministry of Works, Otematata.

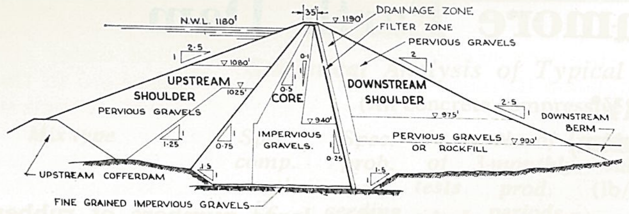

Fig. 1: Typical cross-section through the Benmore earth dam.

cavations provided a very good running surface. The stone showed a mosaic of larger stones firmly interlocked and bound by fines; it was soft enough to be cut by graders when thoroughly wetted, but hard enough to wear slowly.

Where rock could not be used, a clay-bound gravel course topped with a fine running course was used. Provided these roads were kept moist, they gave excellent service. Wheel loads of scrapers were often 30,000 to 32,000 lb; such loads demanded well-constructed roads. Weaknesses, such as pockets of silt several feet beneath the surface, caused considerable trouble until they were removed and the holes backfilled.

2.4.2. *Maintenance*

Five construction graders were needed for sweeping spillage, grading roads, and shaping construction areas. These were assisted by two small graders used only for sweeping stones.

2.4.3. *Haul Road Grades*

Grades were generally chosen to suit loaded machines travelling to the dam, and empty machines returning.

Rimpull and gradeability charts were used to select grades where a choice could be made on those considerations.

The access ramps to the dam on both sides were graded at about 10%. The charts showed that the machines would climb very little faster (vertically) on steeper grades; the machines also suffered loss of traction on steeper grades when the surface became at all wet. Thus 10% was close to the optimum grade.

3. MATERIALS

3.1. General

The typical cross-section of the Benmore earth dam is shown in Fig. 1.

The clayey gravel which was used for the core is rather unusual, as all sizes from 12 in down are present. The relatively coarse grading meant that the core material was compatible with the river gravels in the shoulders, and no narrow awkward transition zones between the core and the shoulders were needed to prevent internal erosion. The dam was therefore rather simpler in its design and construction than is often the case.

The gravels, clayey gravels, and rock-fill were all materials which could be processed and placed using ordinary earthmoving machines. No special or unusual machines were needed.

3.2. Stripping of Borrow Areas

The stripping of overburden was a big task. Eight to 10 feet of overlying materials were removed in places, and the volume of strippings amounted to about two million cubic yards.

In the gravel borrow areas small quantities of organic soils and silts were removed. The silts were the most difficult of the soils to handle: when dry they were easy to load and place in heaps, but when they were wet work came to a standstill.

The strippings from the core borrow area were generally sands and fine gravels with little silt and clay. These though more difficult to load than the dry silts, were easier to handle when wet.

3.3. Shoulder Borrow Areas

3.3.1. *General*

The handling of the gravels was successfully accomplished by:

(a) Intercepting and removing groundwater, which flowed through the deposits in surprising quantities. This was done by excavating perimeter drains to floor level, or lower, with draglines and shovels. The water was then pumped to the river. There was no other way of disposing of the water in the downstream borrow area. Upstream, embankments were used to keep the river out of the borrow area.

(b) Selecting dry gravels with the least silt and generally the coarsest grading for placing in the high-permeability drainage and draw-down zones.

The need to achieve the required permeabilities and densities effectively limited the moisture range at which gravels could be placed. Wet gravels showed springiness after compaction, and machines had difficulty travelling over them. Gravels which were very dry were difficult to compact to the required density.

3.3.2. *Loading*

The shovels worked vertical faces up to 30 ft high. They loaded the gravels easily.

Steep ramps and the most powerful pusher tractors were needed to load scrapers adequately. The gravels were difficult for scrapers to load.

3.4. Core Borrow Area

3.4.1. *General*

The core borrow area, of about 500 acres, was between three and four miles downstream from the dam. The material was generally wetter than the optimum moisture content by two or three per cent.

Trenches were dug to a depth of 50 ft by a 5 yd^3 dragline. They divided the area into blocks containing between a half and one million cubic yards. The trenches collected country run-off and seepage, and drained the area to the river.

Most of the material was carted to the dam with rubber-tyred motor scrapers.

The clayey gravel core material was reluctant to give up its moisture. An attempt to mix and dry the material with a shovel working a vertical face was unsuccessful. However, the following method was used very successfully:

Ramps sloping at about 20% were opened up from the trenches. The material was ploughed and turned by tractors equipped with rippers, tilt dozers, and ploughs. After the first drying the material was dozed into heaps on the ramps. The heaps were often turned over two or three times to speed the drying.

3.4.2. *Loading*

Scrapers were push-loaded by large tractors working down the slope. Later, face shovels and front-end loaders with end-dump wagons were used just as easily as the scrapers in suitable areas. The material was dried and mixed by tractors working in the same way and was finally pushed into heaps 20 to 30 ft high for the shovels to load from.

During early spring and late autumn, drying controlled the output from the borrow area. As the spring days became longer and warmer the need for working the material gradually decreased, until in the summer both drying and watering were necessary. Drying the wetter material enough meant that the drier material became too dry. Some thousands of feet of plastic pipe were laid to the various ramps from the supply mains. The water from a ¾ in hose was usually sufficient at each ramp. The water applied in this way gave a very good control over the mixing and drying process.

Water was used continuously during the summer months and occasionally at other times to give a final touch to improve uniformity and quality.

Generally the core material was handled most easily when its moisture content was within $\pm 0.5\%$ of optimum moisture content. Segregation, weaving, and surface cracking were all at a minimum when the moisture content of the material was in this range.

The water applied ensured that the core material was placed 1% wetter during the height of the summer and that uniformity of moisture was considerably improved. Material without watering was still within the specified limits of -2% to $+1\%$ from optimum, but these limits were too wide for easy placing. Material placed near the dry moisture limit had more trouble meeting the specified density and permeability.

3.4.3. *Core Stockpiles*

Between August and May, 25% of the time available for core carting was lost because of bad weather. No placing was possible during winter. The loss was much greater than had been allowed for. Cycle times from area A to the dam averaged 22 min instead of the 24 min assumed in planning, but this improvement was still not enough, and stockpiling core material close to the dam was adopted (the stockpiles can be seen on the cover). Cycle times from area A to the stockpiles averaged 12.77 min. The effect of putting 753,000 yd^3 through the stockpiles was to drop the average cycle time for all core carting from 22 to 20.25 min. Carting to the core stockpiles continued during the winter months and during the 15% of the time that carting was possible but placing on the dam was not.

Between May 1963 and April 1964, out of 790,000 yd^3 of core material placed on the dam, 460,000 yd^3 came from the stockpiles.

Stockpiles are a time-honoured construction and manufacturing expedient. At Benmore they allowed advantage to be taken of good weather in the summer, and their use made the difference between success and failure.

3.5. Dam

On the dam all carting plant was directed to the placing areas by spotters, supervisors who controlled the unloading and the layer thicknesses. Other supervisors made sure that the materials were placed in the proper zones and that zone boundaries were maintained, in the right places. Continual attention had to be given to preventing segregation, particularly at zone boundaries.

4. ESTIMATING

4.1. General

This rate of production was calculated from estimated values of: the quantity to be moved; the working hours available; the availability of machines allowing for repairs and maintenance; the cycles times; the efficiency, or percentage of working hours actually worked; and the average load sizes.

The numbers of carting machines and their associated loading machines required were estimated from the rate of production necessary to complete the work by 1964.

4.2. Time

In early planning, the requirements of diversion of the river in autumn 1961 and first power in 1964 gave a time of two and a half years or about 400 to 450 working days.

Diversion took place in August 1960, eight months early. The date for first power was changed to 1965. The construction time was, therefore, fixed at four years.

In the U.S. two shifts would have been worked, perhaps not during the first but certainly during the following years. However, here in New Zealand (2):

> Considerations weighed in favour of working one shift per day of 9 hours duration, extending to a maximum of 12 when weather conditions and other factors permitted. The principal reasons for this were:
>
> (a) The general manpower shortage at the time made it appear unlikely that sufficient men to work two shifts would be available.
>
> (b) Winter conditions would certainly dictate a return to a single shift of a restricted nature, with a consequent laying off of men.
>
> (c) The work could be completed within the available time, working one shift, provided equipment requirements were viewed in this light.

Shortage of men affected the job till the end. Frequently there were not enough men to maintain one shift comfortably.

TABLE 1

Comparison of Estimated with Observed Machine Performance

Estimate	*Upstream shoulder*	*Core*	*Downstream shoulder*
Haul distance one way (ft)	5,300	16,300	5,300
*Cycle times (min)	18.05 s	24.05 s	18.0 w
**Offered working hrs/yr.	2,100	2,100	2,100
†Load size (yd³)	13.9 s	13.9 s	11.1 w
Availability (%)	75 (all hauls)		
Efficiency	50 min hr (83%)		

Observed	*Upstream shoulder*	*Core*	*Downstream shoulder*
Haul distance one way (ft)	6,000	18,500	5,800
Cycle times (min)	16.15	§20.25 22.00	13.58
Offered working hrs/yr.	2,000	††2,000 1,250	2,000
Time lost (% of total) weather and effects	10	‡25 10	10
Loader under repair	0.5 s } all hauls		
	4.0 w } all hauls		
Other causes	1 to 6 } all hauls		
Load size	19.4 to 15.8 s	15.1 s	17.4 to 15.8 s
Cubic yards	16.8 to 9.2 w 13.2 average	12.6 to 6.3 w 14.42 average	17.0 to 9.2 w 14.65 average
Availability (%)	93 to 80; average 83		
Efficiency	45 to 55 min hr; average 50 min hr.		

Notes:

*Estimated cycle times have been increased by the inverse of the efficiency to allow direct comparison with observed cycle times.

†Based on rated payloads and fill density of 150 lb/ft³.

**Adjusted for standing time and delays due to bad weather.

††1,250 hours are the hours/year carting into the dam. 2,000 hours include carting into dam and stockpiling close to the dam during winter.

‡25% is time lost during core-material carting season, August to May; 10% includes stockpiling during season and winter, when material is not being placed on the core.

§20.25 min cycle time for all core carting; 22.00 min cycle time for Area A to dam (excludes stockpiles).

s = scraper. w = end-dump wagon.

4.3. Machine Performance

4.3.1. *Cycle time*

Cycle times for the various hauls were estimated by standard methods.

4.3.2. *Availability*

Availability was conservatively taken to be 75%. That figure was considerably improved on by most of the groups of machines that were new, or nearly new, at the beginning of the job. The achieved average of 83% was weighted down by the poorer performances of some groups of machines that were old at the start.

The falling off in availability over the last year can be attributed to many causes, two of which were the increasing age of machines, and increasing delays in securing sufficient spare parts. Except for spare parts, conditions at Benmore were favourable.

4.3.3. *Spare Unit Assemblies*

Extra engines, winches, transmissions, and other assemblies, were bought along with some of the larger groups of machines.

Makers are paying great attention to quick and easy removal and replacement of assemblies. At Benmore the extra investment was recovered many times from improved availability and the smoother flow of work through the repair shops.

4.3.4. *Servicing and Fuelling*

Servicing and fuelling were carried out at times when these activities would have little effect on output. Contractors' machines were all serviced and fuelled after work. Most Ministry of Works carting plant and shovels were attended to in the evening after 5 p.m.

Other important items such as pusher dozers were fuelled during meal breaks. Only the smaller machines were serviced and fuelled during working hours. Major oil changes were confined to non-working Saturdays and Sundays.

Interruptions of this kind were avoided as much as possible.

4.3.5. *Efficiency*

In estimates the efficiency was taken as a 50 minute hour or 83%. Machines employed on tonnage contracts probably achieved a 55 minute hour, or 92%. Machines hired by the hour achieved 45 to 50 minutes.

4.3.6. *Average Load Size*

Production estimates were based on machines having 40,000 and 55,000 lb payloads. Fill density was taken as 150 lb/ft³. Payload governed here, not volume, because the materials were very heavy in the bank, the bowl, and the dam.

Payloads were generally higher than the equipment manufacturers recommended: some groups of machines carried an average of 40% more without noticeable stress.

5. PROGRESS AND COSTS

5.1. General

The Benmore project demanded an efficient progress and costing organisation; without some processing equipment an army of clerks would have been needed to handle the data.

Late in 1960, 40-column data-processing machinery was set up on the project. The worth of this equipment has been proved. It has the ability to digest masses of data, to tabulate, and to print out information. It is doubtful whether the costing and plant performance data required by the Ministry of Works could have been obtained otherwise.

Table 1 compares estimated with observed plant performance. Generally, performances and costs were better than expected.

Figure 3 sets out the flow of data through the costing organisation as it applied to the earth dam. The system produces:

(a) The output tallies of all earth-carting machines.

(b) The conversion of tally to placed quantities in the dam.

(c) The timekeeping of all earthmoving machinery, with the time tabulated under various headings.

(d) Plant performance, namely cycle times and availabilities.

(e) Costs.

5.3. Tallying and Timekeeping

5.3.1. *Daily Tally*

Each working day a summary sheet was prepared of the previous working day's tallies. This sheet grouped machines first by source and destination of the material being carted and secondly by type, make, and model. The loads from each machine were entered hour by hour across the sheet. The total loads for each machine were found. The total for each group of machines was also converted to the volume of material placed in the dam. Finally all the different volumes were added up to give the grand total placed for the day.

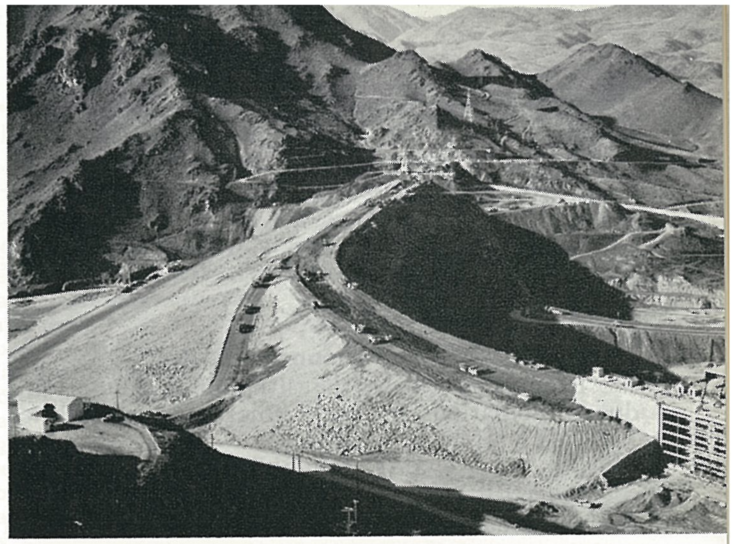

Fig. 2: Placing operations, February, 1964. (Downstream is to the right of the picture).

5.3.2. *Checks*

The tally sheet gave three very important checks on the running of the job. They were:

(a) A check of progress against the target set for the immediate two-week period.

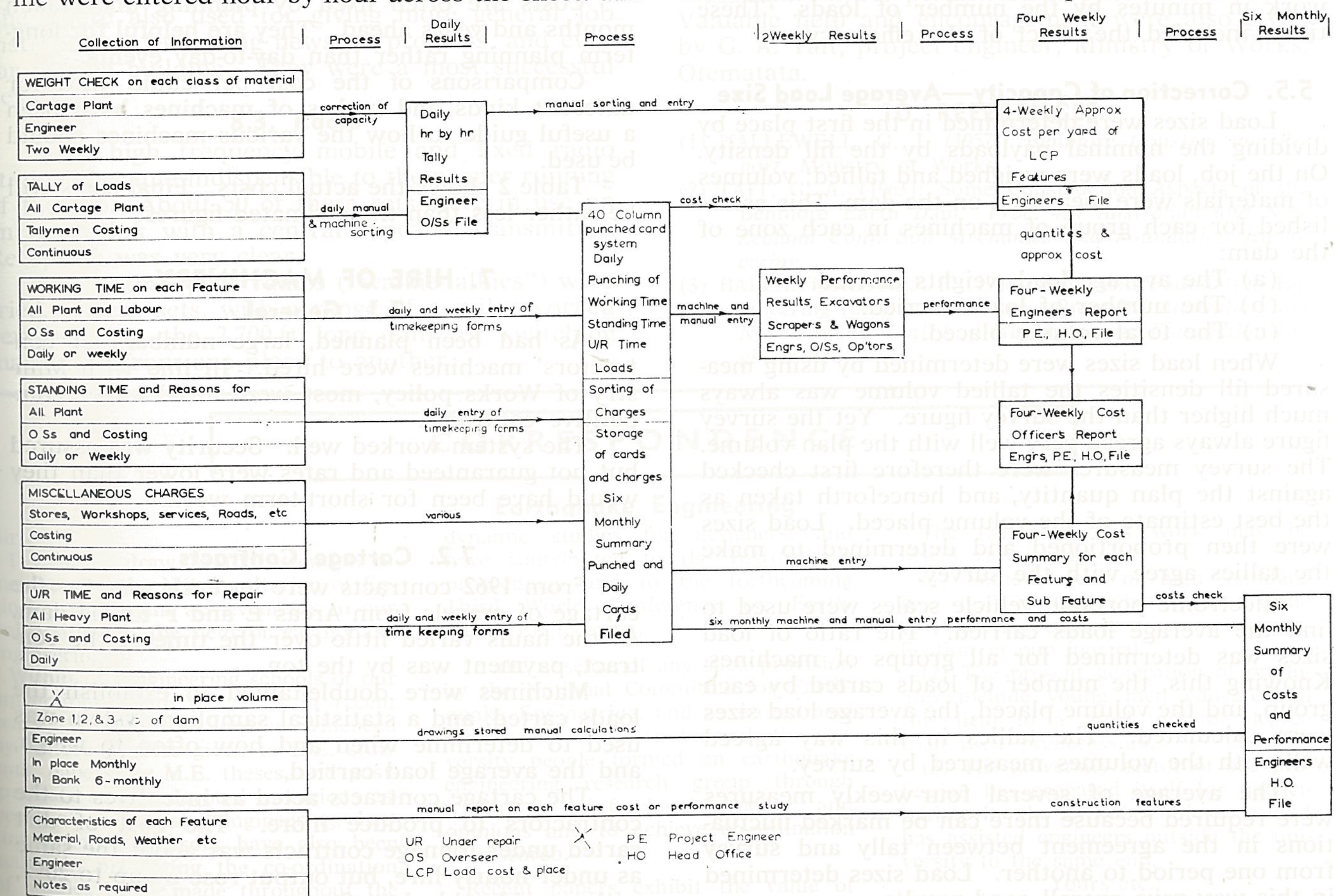

Fig. 3: The flow of data through the costing organisation.

(b) An independent check of machine timekeeping. Two or three hours of machine time saved per day more than paid for the expense of tallying.

(c) A check of bottlenecks and gross inefficiencies.

Copies of the tally sheets were distributed to overseers; this helped to foster a friendly sense of rivalry between sections.

5.4. Performance Results

Every two weeks the 40-clumn tabulator produced tabulations for cycle times and availabilities.

5.4.1. *Availability*

For each machine and groups of machines of the same make, type, and size the tabulator printed a statement of the hours spent working, under repair, and standing. From this the percentage availability was calculated.

Repairs were broked down under various headings according to the type of machine. These tables and the availability percentages indicate the virtues and defects of various makes and types of machines.

5.4.2. *Cycle Times*

The hours spent on each job and the loads carted were recorded for each machine. A fortnightly tabulation allowed cycle times for each machine and group of machines to be calculated. The cycle times were arrived at by dividing the work in minutes by the number of loads. These times included the effect of the efficiency.

5.5. Correction of Capacity—Average Load Size

Load sizes were determined in the first place by dividing the nominal payloads by the fill density. On the job, loads were weighed and tallied; volumes of materials were measured on the dam. This established for each group of machines in each zone of the dam:

(a) The average load weights carried.
(b) The number of loads carried.
(c) The total volume placed.

When load sizes were determined by using measured fill densities the tallied volume was always much higher than the survey figure. Yet the survey figure always agreed very well with the plan volume. The survey measures were therefore first checked against the plan quantity, and henceforth taken as the best estimate of the volume placed. Load sizes were then proportioned and determined to make the tallies agree with the survey.

Electronic portable vehicle scales were used to find the average loads carried. The ratio of load sizes was determined for all groups of machines. Knowing this, the number of loads carted by each group, and the volume placed, the average load sizes were calculated. The tallies in this way agreed well with the volumes measured by survey.

The average of several four-weekly measures were required because there can be marked fluctuations in the agreement between tally and survey from one period to another. Load sizes determined in this way gave overall good results.

Thus a machine of 24 yd³ struck capacity came to be rated at about 16 yd³ when carting core materials. Load sizes used during 1964 are shown in Table 1.

6. COSTS

6.1. Cost Account

All parts of the Benmore project are identified by a written description and a five-figure code number. The first three figures represent a major part, the last two the particular operation. For example 231.20 could mean earth dam load cart and place core material. Cost elements such as labour, materials, workshop charges, and contracts are given a two-figure code. All costs and man-hours are charged against the feature numbers.

Every months the 40-column tabulator produces a statement of expenditure on each feature. Every second month a "to date" statement is produced of expenditure since the beginning of the job.

The codes and the punched-card equipment allow the work to be broken up into as many features as are required. The break-down needs to be logical and consistent with the object of costing.

6.2. Unit Costs

Direct costs per cubic yard of materials placed on the dam were produced four-weekly, both for the preceding four weeks and the average to date. These costs have been presented graphically since 1961.

Costs are often fixed by planning undertaken months and years ahead. They are helpful for long-term planning rather than day-to-day events.

Comparisons of the cost per cubic yard for different kinds and makes of machines have been a useful guide to how the various machines should be used.

Table 2 shows the actual costs. Final costs will be rather less than the estimated figures.

7. HIRE OF MACHINERY

7.1. General

As had been planned, large numbers of contractors' machines were hired. In line with Ministry of Works policy, most were hired under competitive contracts.

The system worked well. Security was assured but not guaranteed and rates were lower than they would have been for short-term work.

7.2. Cartage Contracts

From 1962 contracts were let each year for the cartage of gravels from Areas E and F to the dam. As the hauls varied little over the time of the contract, payment was by the ton.

Machines were double-tallied to establish the loads carted, and a statistical sampling system was used to determine when and how often to weigh, and the average load carried.

The cartage contracts acted as incentives to the contractors to produce more. The cost of dirt carted under tonnage contracts was about the same as under hourly hire, but output rose by up to 20%, with considerable benefit to progress.

Supervision of machines working under cartage contracts was much easier. These contracts were successful both from the Ministry of Works' and the contractors' points of view.

8. SUPERVISION

8.1. General

Machines account for 86% of the cost of Benmore earth dam. The aim was to watch all areas of the job and also the servicing and repair of machines.

An overseer and one or two foremen were placed in each borrow area. On the dam an overseer and four foremen controlled placing.

An innovation was the setting up of a plant operating section, of one overseer and two foremen. They were responsible for quarters, services, and discipline for all Ministry of Works machines and their drivers. These operating people were attached to the mechanical division but acted on instructions from earth dam supervisors as to when and where machines were required. The arrangement worked very well. This section had the confidence of both the earth dam supervisors and the mechanical division, on whose services the successful completion of the dam depended.

8.2. Fortnightly Programmes

All the sections of the Benmore project produced fortnightly construction programmes which listed jobs to be done and quantities to be placed. They were also used for giving more general job instructions, for giving news on progress, and even for morale building. They were a most successful device.

8.3. Radio

Very high frequency mobile and fixed radio stations became indispensible to the proper running of the job. About 50 of these sets were in use on an open link with a central repeater transmitter. Reception was very clear.

Later, small pack radios ("walkie-talkies") were tried. These sets, with a range of a mile, worked very well on the 2,700 ft long dam for switching machinery from one place to another.

TABLE 2
Direct Costs

Item	*Quantity* (yd³)	*Unit rate* (d.)	*Amount* (£)
Excavate core material, deposit and compact in dam embankment (2½ mile lead).	3,809,000	149.5	2,372,556
Excavate shoulder material other than rock deposit and compact in dam embankment (average lead ¾ mile)	9,467,000	59.5	2,339,616
Deposit and compact rock from required excavation or spoil dump as shoulder material average lead ½ mile)	2,018,000	17.4	146,000
Grout curtain under dam		lump sum	52,000
Piezometer installation and compacting gauges.		lump sum	13,991
Totals	15,294,000		4,924,163

Pack radios will be used more extensively as they become available. They can be used advantageously on most construction works.

9. ACKNOWLEDGMENTS

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CORRESPONDENCE

Earthquake Engineering

Sir,

I wish to draw to the attention of members of the N.Z. Institution of Engineers the recent achievements in our universities in the field of earthquake engineering.

Within the engineering schools of our universities, there has been in recent years a surge of activity as evidenced by lecture courses given to B.E. students, papers for M.E. theses, and postgraduate studies devoted to various aspects of earthquake engineering. Lecturers and professors have also been active in promoting the co-ordination of studies being made throughout the country, have been engaged to make dynamic studies for designers, and have contributed to the Institution's proceedings and to the forthcoming Third World Conference on Earthquake Engineering.

In the absence of any such provision by the National Committee for Earthquake Engineering, and as no national association had been formed, the university people formed an earthquake engineering research group through which to interchange news and opinions and to achieve co-ordination of research.

Recent papers exhibit the value of the liaison which the group has created.

The fruits of this work may be briefly recounted:

(1) Some papers of high standard have been written which are of value to practising engineers and merit publication in our journal.

(2) The present generation of graduates include young men educated in this field to a much greater degree than their predecessors.

(3) The university sector of our profession has prepared itself for participation in the World Conference and has assisted engineers outside the university to the same end.

Yours etc.,
R. J. Paterson Garden.