DASA SC318

Technical Report **R 650**

DYNAMIC TESTS OF MODEL CONCRETE

November 1969

Sponsored by

DEFENSE ATOMIC SUPPORT AGENCY

NAVAL CIVIL ENGINEERING LABORATORY

Port Hueneme, California

This document has been approved for public release and sale; its distribution is unlimited.

DYNAMIC TESTS OF MODEL CONCRETE

Technical Report R-650

YF008-08-02-126, DASA SC318

by

John M. Ferritto

ABSTRACT

The objective of this project was to evaluate the dynamic properties of modeling materials. Dynamic tests were conducted on microconcrete with no. 4 and no. 30 maximum aggregate size, and gypsum concrete with no. 4 maximum aggregate size. The effects of strain rate (up to 2.5 in./in./sec) on ultimate compressive strength were obtained. The results are compared with results of dynamic tests conducted on prototype concrete by others. Microconcrete with a no. 4 maximum aggregate gives good correlation with prototype values of dynamic strength increase. The ratio of dynamic to static modulus of elasticity with increasing strain rate and dynamic strength increase factor also gives good correlation. Microconcrete with a maximum aggregate size of no. 30 gives dynamic increase factors somewhat lower than those of the prototype. The ratio of dynamic to static modulus of elasticity with increasing strain rate is greater than that of the prototype or microconcrete with no. 4 maximum aggregate. Both microconcretes experience higher strains at ultimate load than the prototype. Gypsum concrete experiences dynamic strength increase factors of approximately half those of the prototype. It may be significant that the increase in modulus of elasticity with increasing strain rate for gypsum concrete is not similar to that of prototype concrete. Strains in gypsum concrete at ultimate load are slightly higher than those for prototype concrete.

This document has been approved for public release and sale; its distribution is unlimited.

Copies available at the Clearinghouse for Federal Scientific & Technical Information (CFSTI), Sills Building, 5285 Port Royal Road, Springfield, Va. 22151

CONTENTS

INTRODUCTION

The application of small-scale models to problems in the design and analysis of structures has been increasing in recent years. The structural model can be used to check the validity of analytical solutions, or to form a basis for establishing simplifying assumptions for mathematical solutions. The usefulness of models is especially apparent in the design of highly complex structures where mathematical analysis may be difficult, time consuming, or inaccurate. Another feature of models is the potential ease with which they can be altered for comparative studies of several designs or for studies at different stages of construction. Small-scale models can be tested in the laboratory and their response to dynamic blast loads can be determined. Otherwise the field testing of large-scale structures, involving great expenditures of time, effort and money, would be required.

A research project was initiated at NCEL under the sponsorship of the Defense Atomic Support Agency (DASA) to further the development of modeling techniques. The primary objective of the first phase of the project was to develop a mix design procedure for concrete used in small-scale models. A technical report was written which establishes a procedure for properly proportioning a model concrete mix that produces strengths in the model essentially the same as those in the prototype.[1] In this procedure, cylinder sizes for compression testing are chosen such that the cross-sectional dimensions are approximately the same as those for a model. For example, 1 x 2-inch cylinders are used with a model having 1-in.^{2} columns. It has been shown[2] that with decreasing specimen size an increase in ultimate compressive strength is observed. It is felt that by keeping the test cylinder in proportion to a key dimension of the model, as is done in prototype construction using a standard size 6 x 12-inch cylinder, the model strength may be predicted more accurately. The maximum aggregate size was established as one-eighth of the minimum dimension of the model; this proportion is used in large-scale prototype concrete. Standard aggregate gradations were established for various maximum sizes.

The rate at which a concrete cylinder gains strength depends on cylinder size, with smaller cylinders gaining strength faster. Therefore, to accurately predict compressive strength, it is necessary to test smaller cylinders at an earlier age. It was experimentally determined that

$$\text{Test Age} = 12 + 4d \qquad (1)$$

where time is expressed in days and **d** is the cylinder diameter in inches.

PRESENT WORK

The primary objective of this phase of the project was to evaluate the dynamic properties of modeling materials when compared to the characteristics of large-scale prototype concrete, and to determine if strength prediction relationships developed for prototype concrete under dynamic loads were applicable to model materials.

Having established a procedure which duplicates the strength of a prototype concrete in a model, it was of interest to determine if the increase in strength in the model obtained by increasing the rate of loading would be the same as in the prototype. Graphs were developed[3,4,5] that predict increases in ultimate compressive strength of prototype concrete with an increase in loading rate. According to the principles of dimensional analysis outlined in the Appendix, the testing of a dynamic model requires that the length scale constant, S_ℓ, equal the time scale constant, S_t. To directly model the prototype concrete, the ultimate compressive stress of the model should be the same as the prototype. Thus, the model material must have the same strength properties as the prototype concrete, but the similitude relationship requires the strain rate in the model to be S_ℓ times the strain rate in the prototype. Since the ultimate strength of concrete increases with strain rate, the model material must have a lower static ultimate strength than the prototype concrete so that at their corresponding strain rates they will have the same ultimate strengths.

The dynamic increase factors to be applied to the static ultimate strengths of the model so as to produce dynamic strengths equal to the prototype at differing strain rates must be evaluated. Size effect (the increase in strength observed by reduction in size[2]) complicates the evaluation of the dynamic strength increase factor of a model. A series of tests was conducted varying the rate of loading in order to evaluate the dynamic characteristics of model concrete.

TEST PROCEDURE

Casting

Test cylinders were cast using the same materials, aggregate gradations, and procedures described in Reference 1. Type III portland cement and Ultracal 30, manufactured by the U. S. Gypsum Company, were used. The aggregate was San Gabriel River wash sand and gravel sieved to standard gradations. All specimens were cast in specially constructed plexiglass forms. Batches of model concretes were mixed, cast into cylinders, cured, and capped as described in Reference 1 and outlined in Table 1. The cylinders were tested at ages predicted from Equation 1.

Table 1. Model Concrete Specimens

Type of Cylinder	Number of Cylinders	Size of Cylinder (in.)	Cement	Maximum Aggregate Size	Age at Test (day)
solid	16	1-1/2 x 3[a]	Type III portland	no. 4	18
hollow	16	1 x 5/8 x 2[b]	Type III portland	no. 30	13
solid	16	1-1/2 x 3[a]	Ultracal 30 gypsum	no. 4	2

[a] Diameter x height
[b] Outer diameter x inner diameter x height

Testing

Four cylinders from each set of sixteen were tested on a 30,000-pound-capacity Universal Testing Machine using a stress rate of 35 psi/sec as the static values. Load—strain diagrams were automatically recorded on a plotter using 1-inch strain gages mounted on the cylinders as inputs to the plotter (Figure 1).

The twelve remaining cylinders were tested in three groups on the dynamic testing machine with three different loading rates. A pneumatic-hydraulic machine (Figure 2) which utilizes air pressure in hydraulic accumulators supplied the necessary energy. The hydraulic pressure was equalized on the top and bottom of the main piston before each test. The head velocity, which controls the loading rate, was varied by regulating the rate of flow of hydraulic fluid on the botton of the main piston. Because the main piston operated downward, compression tests were, therefore, conducted in the lower section of the machine. The specimen was centered on a load cell. The top bearing head, which was attached to the lower piston rod, was screwed down upon the specimen. A more detailed description of the machine and its operation may be found in Reference 6. Readings of the load cell, head movement, and strain were automatically recorded on tape and observed on an oscilloscope during testing. Large noise spikes were observed during the tests; however, they did not appear to influence test results.

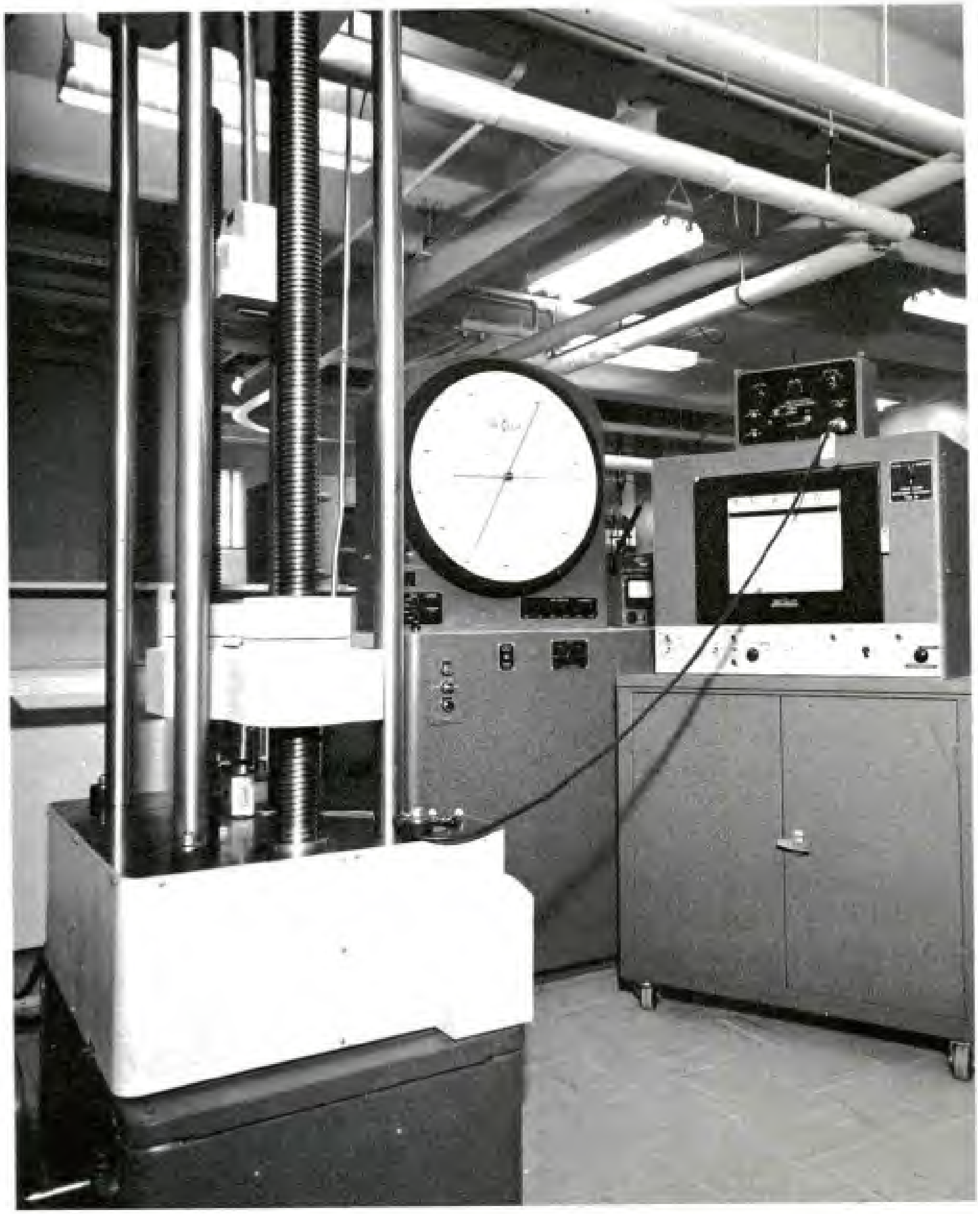

Figure 1. Static compression testing machine.

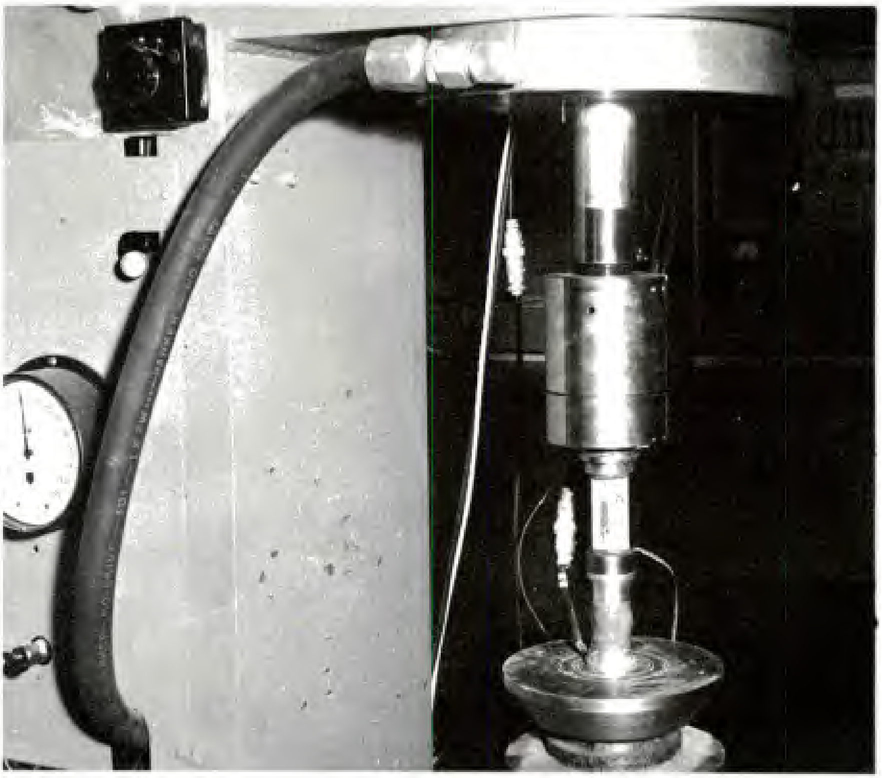

Figure 2. Dynamic compression testing machine.

Test Results

The raw data readings of the load cell, head movement, and strain were reduced using an analog-to-digital converter and were automatically plotted with a sampling rate of 4,000 samples per second. A total of 200 samples were taken for each curve. A typical plot is shown in Figure 3. From these curves the stress and strain rates were computed by taking the ordinate value and dividing it by time. The stress rate and strain rate were computed directly, independently of the material properties. It should be noted that the head movement and load cell readings are linear; the strain rate is based on an approximation of a linear range. A computer was also programed to give stress–strain plots from which the secant modulus of elasticity was obtained. Typical curves are shown in Figure 4. A summary of the test results is presented in Tables 2, 3 and 4.

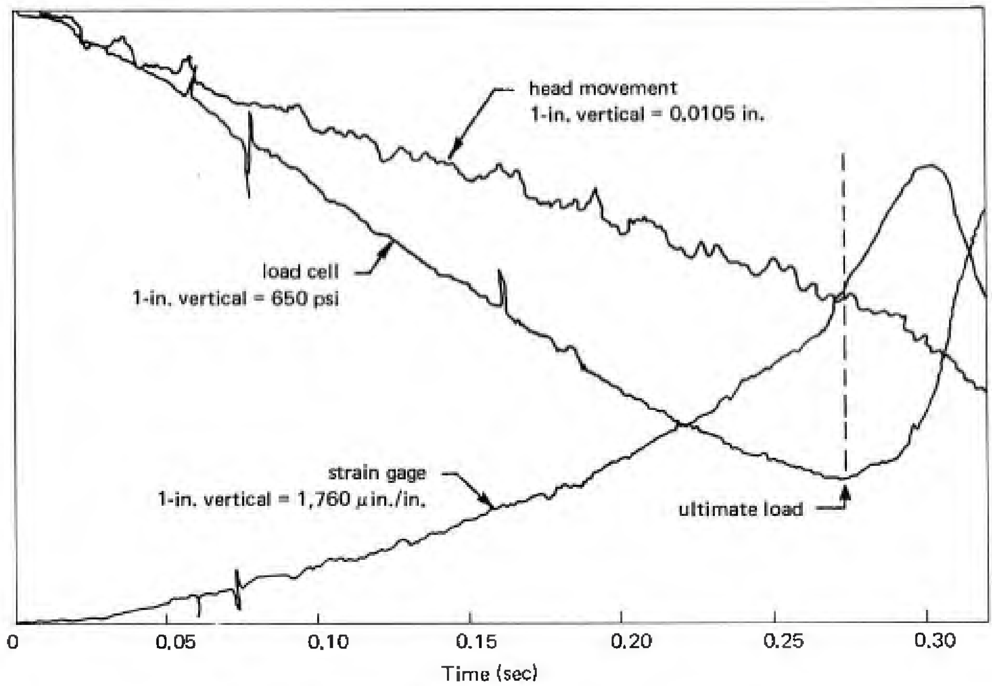

Figure 3. Typical computer plots of raw data for dynamic compression tests.

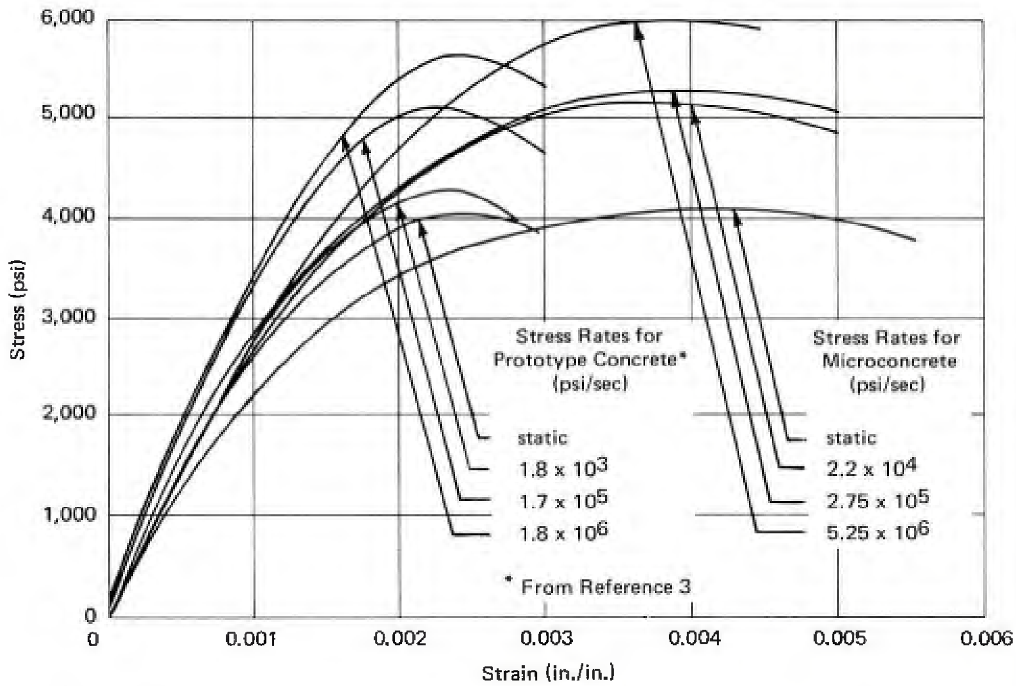

Figure 4. Comparison of stress–strain curves for various rates of loading.

Table 2. Results From Compression Tests on Solid Microconcrete Cylinders With No. 4 Aggregate

Cylinder No.	Stress Rate (psi/sec)	Strain Rate (in./in./sec)	Compressive Strength (psi)	Secant Modulus of Elasticity[a] (psi x 10^6)	Strain at Maximum Stress (in./in. x 10^{-6})
1	35	approximately 1.5×10^{-5}	4,100	2.51	3,640
2	35		4,240	2.19	4,200
3	35		4,280	2.25	4,210
4	35		3,920	2.13	3,710
5	2.20×10^4	9.23×10^{-3}	5,320	2.66	3,430
6	2.23×10^4	9.97×10^{-3}	4,960	2.49	4,120
7	2.15×10^4	10.28×10^{-3}	5,100	2.56	3,720
8	2.21×10^4	8.85×10^{-3}	5,490	2.84	3,900
9	2.77×10^5	0.148	5,280	2.79	3,520
10	2.70×10^5	0.153	4,950	2.55	3,820
11	2.71×10^5	0.157	5,680	2.92	4,110
12	2.62×10^5	0.151	5,550	2.70	4,160
13	4.75×10^6	2.98	6,120	2.56	4,020
14	5.47×10^6	3.73	5,810	2.99	3,150
15	5.35×10^6	2.98	6,430	2.76	4,150
16	5.46×10^6	3.30	6,020	2.23	4,550

[a] To strain of 0.1%

Table 3. Results From Compression Tests on Hollow Microconcrete Cylinders With No. 30 Aggregate

Cylinder No.	Stress Rate (psi/sec)	Strain Rate (in./in./sec)	Compressive Strength (psi)	Secant Modulus of Elasticity[a] (psi x 10^6)	Strain at Maximum Stress (in./in. x 10^{-6})
1	35	approximately 1.7×10^{-5}	4,280	1.98	—
2	35		3,600	2.04	3,350
3	35		4,240	1.96	4,100
4	35		4,440	1.96	4,850
5	4.44×10^4	0.0242	5,550	2.65	4,180
6	4.34×10^4	0.0260	5,320	2.49	3,800
7	4.28×10^4	0.0261	4,350	2.32	3,010
9	8.76×10^5	0.485	5,310	2.70	3,380
10	10.62×10^5	0.645	5,270	2.62	3,930
11	9.04×10^5	0.550	5,580	2.90	3,350
12	8.56×10^5	0.419	5,090	2.60	3,700
13	9.16×10^6	7.91	5,960	3.00	3,630
14	9.53×10^6	8.35	5,970	3.67	3,580
15	9.26×10^6	10.53	6,170	2.40	4,480
16	9.15×10^6	6.06	5,710	2.62	3,690

[a] To strain of 0.1%

Table 4. Results From Compression Tests on Solid Gypsum Concrete Cylinders With No. 4 Aggregate

Cylinder No.	Stress Rate (psi/sec)	Strain Rate (in./in./sec)	Compressive Strength (psi)	Secant Modulus of Elasticity[a] (psi x 10^6)	Strain at Maximum Stress (in./in. x 10^{-6})
1	35	approximately 1.7×10^{-5}	3,890	1.93	3,000
2	35		4,040	1.94	—
3	35		4,200	2.06	—
4	35		3,980	2.07	—
5	1.30×10^4	6.84×10^{-3}	4,330	2.42	2,880
6	1.10×10^4	4.62×10^{-3}	4,260	2.65	2,270
7	1.00×10^4	4.86×10^{-3}	4,180	2.44	2,750
8	1.04×10^4	5.02×10^{-3}	4,250	2.65	2,450
13	5.53×10^5	0.377	4,710	2.62	3,210
14	5.21×10^5	0.357	4,550	2.60	2,900
15	4.11×10^5	0.255	4,880	2.64	3,080
16	3.90×10^5	0.328	4,410	2.60	2,950
9	4.52×10^6	2.68	5,170	2.82	3,600
10	4.40×10^6	3.01	5,400	2.10	4,400
11	4.86×10^6	2.93	5,590	1.74	4,600
12	4.66×10^6	2.62	5,410	2.21	3,660

[a] To strain of 0.1%

DISCUSSION

The test results from this report are compared to results given in References 3, 4, 5 and 7; the plots are shown in Figures 5, 6, 7 and 8.

Microconcrete

It appears that the dynamic strength increase factor (f_c' dynamic/f_c' static) for microconcrete with a no. 4 maximum aggregate, gives good correlation with prototype values, considering the variation in the prototype results (Figures 5 and 6). For this set of tests, the effect of reducing the size of the specimen on the ultimate compressive strength was found to be adequately compensated for by employing the procedure of testing established in Reference 1. A smaller specimen will give strengths comparable to the prototype concrete even under dynamic loads if it is tested at the appropriate age indicated in Equation 1. The curves used as standards in prototype design procedures for predicting increases in ultimate strength with increasing strain rate are sufficiently close to be utilized in model design and analysis with the same degree of uncertainty.

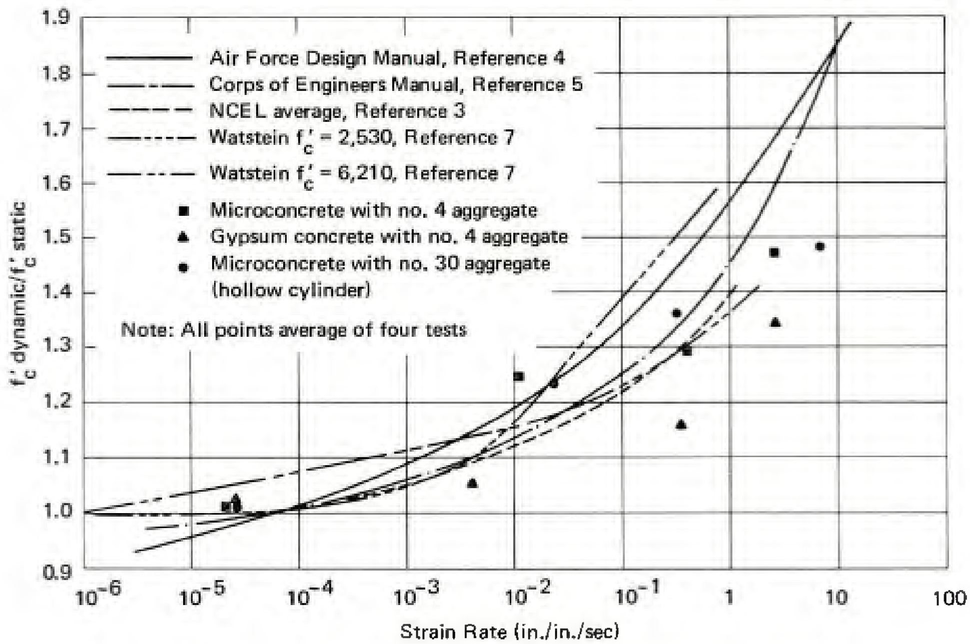

Figure 5. Ratio of compressive strengths versus strain rate.

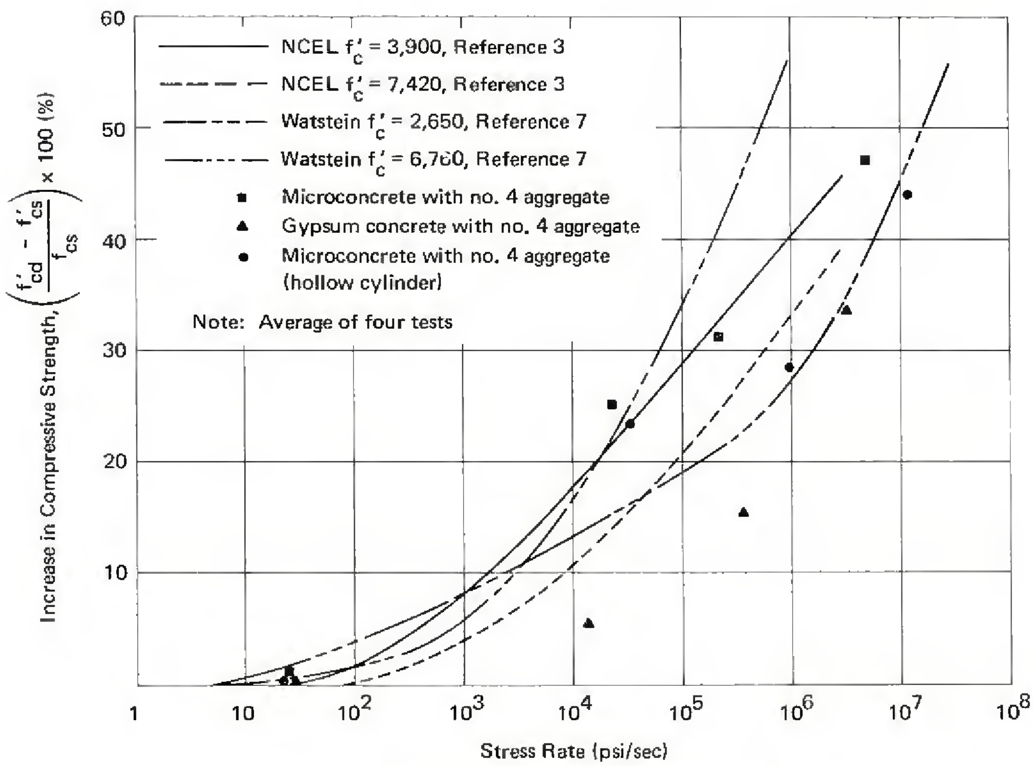

Figure 6. Percentage increase in compressive strength versus stress rate.

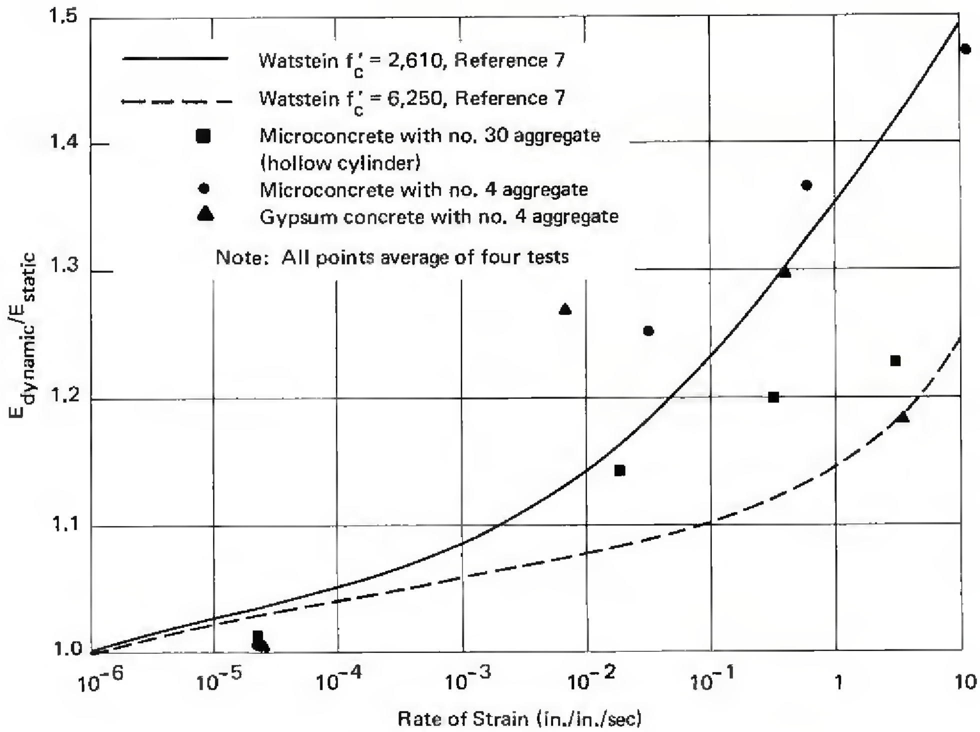

Figure 7. Strain rate versus ratio of modulus of elasticity.

The increase in the ratio of dynamic to static modulus of elasticity with increasing strain rate and dynamic strength increase factor (Figures 7 and 8) gives reasonable correlation with prototype concrete results. Considering its dynamic characteristics, this size microconcrete is well suited for use in direct models involving dynamic effects without special adjustment by a dynamic scale factor. It is important to note the increase in strain at failure and the slightly lower modulus of elasticity in the static and the dynamic ranges. These deviations are characteristic of the material's "microstructure." The reduction in size of the aggregate in the microconcrete will increase the surface area to be covered by the cement paste. Thus an increase in cement which has a lower modulus of elasticity than the aggregate is required in order to maintain strength. The consistency of the microconcrete and volume of aggregate are major factors in determining the amount of ultimate strain and the modulus of elasticity.

It should be noted that using a strain rate S_ℓ times faster in the model will affect the final value of the modulus of elasticity. A model having a lower static strength and static modulus of elasticity than the prototype will have a higher dynamic increase factor to produce equal dynamic strength and a higher ratio of dynamic to static modulus of elasticity. This increase in the dynamic-to-static-modulus-of-elasticity ratio for the model over that for the prototype will partly offset the lower initial static value of the model.

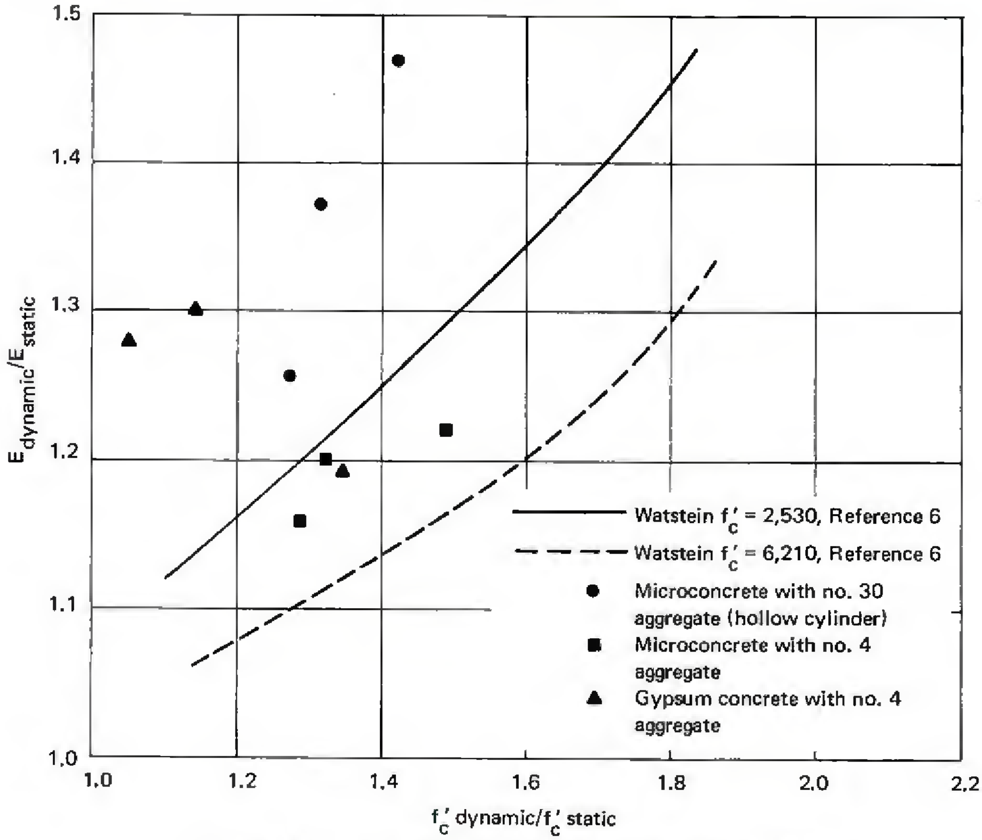

Figure 8. Ratio of dynamic strength increase factor versus ratio of modulus of elasticity.

The results of the hollow cylinders of microconcrete with no. 30 maximum aggregate size indicate dynamic strength increase factors somewhat lower for higher rates of straining (1 in./in./sec) than the range expected (Figures 5 and 6). The ratio of dynamic to static modulus of elasticity with increasing strain rate is greater than that of the prototype or microconcrete with no. 4 aggregate (Figure 7). The combined effect of increase in strength and increase in modulus of elasticity, Figure 8, shows microconcrete with no. 30 aggregate to be more elastic for a dynamic load than predicted from the prototype concrete. The effect of this variation may be significant in construction of a model. This material is not as well suited for a dynamic model as is microconcrete with a no. 4 aggregate. Further evaluation of these results cannot be made because the effect of changing the shape of the specimen is unknown.

Gypsum Concrete

The dynamic strength increase factor for the gypsum concrete cylinders is somewhat less than that expected by comparing it to the prototype curves, Figures 5 and 6. The ratio of modulus of elasticity for increasing load rates does not follow the same pattern as that of the prototype concrete (Figures 7 and 8). This may be a significant factor in the design and analysis of a model. The static strength of a gypsum concrete model must be selected so that the dynamic strength increase factor for the strain rate to be used will produce strengths equal to the strength of the prototype at its strain rate. The increase in modulus of elasticity for this rate will probably vary significantly from that of the prototype. This variation will be most critical when the loading rate varies significantly with time, such as a blast load rather than a controlled constant load rate in a testing machine. The variation of strain rate with time will produce a modulus of elasticity in the model which is initially greater, reaches a maximum, and then decreases. The prototype modulus of elasticity will gradually increase for all increasing strain rates.

Gypsum concrete experiences higher ultimate strains than those for the prototype concrete, but the strains are not as large as those for microconcrete. There is an increase in ultimate strain with an increase in strain rate for gypsum concrete; this is not noticeable for microconcrete. The suitability of this gypsum concrete will depend on the particular model and loading rate. Scale factors which vary with strain rate must be applied to predict strengths and modulus of elasticity.

FINDINGS AND CONCLUSIONS

1. The dynamic properties of microconcrete with no. 4 maximum aggregate give good correlation with prototype concrete values.

2. The dynamic strength increase factors determined from prototype design curves are adequate for use in designing a model constructed from microconcrete with no. 4 maximum aggregate.

3. The increase in strength of the concrete with reduction in size of the specimen is adequately compensated for by testing at an earlier age, even for dynamic loadings.

4. Microconcrete with a maximum aggregate size of no. 30 experiences lower dynamic strength increase factors and greater ratios of increase in modulus of elasticity for increase in strain rates than the prototype concrete.

5. Strains at ultimate in microconcrete are greater than strains at ultimate in the prototype concrete.

6. Gypsum concrete experiences dynamic strength increase factors somewhat less than those of the prototype concrete; the ratio of dynamic to static modulus of elasticity with increase in strain rate does not behave like the ratio for the prototype concrete.

ACKNOWLEDGMENT

The planning of the test program, casting of the cylinders, and reduction of data were done by the late David Fuss, Research Structural Engineer at NCEL. The dynamic tests were performed by Walter Cowell, former Research Materials Engineer at NCEL. Gaging of the cylinders was accomplished by Dale Harrington former Engineering Technician at NCEL.

Appendix

DIMENSIONAL ANALYSIS

To achieve similitude it is necessary to maintain a constant relationship of significant effects in model and prototype. In a problem of structural dynamic response the two basic properties which interact to give the resultant behavior are the resistance properties of a structure to deflection at the rate of straining, and the loads applied. Nine quantities shall be considered as significant to the dynamic response of a structure, neglecting the effects of dead load. They are expressed in terms of length, L, time, T, and force, F, as follows:

Q	Loading pressure (FL^{-2})
t	Duration of pressure (T)
ℓ	Geometry parameter (L)
U	Displacement (L)
ρ	Specific mass (force acceleration) ($FL^{-4}\ T^2$)
ϵ	Strain
σ	Stress (FL^{-2})
E	Modulus of elasticity (FL^{-2})
ν	Poisson's ratio

To completely define the relations of model and prototype, six dimensionless π terms must be established.

$$\pi_1 = \epsilon$$

$$\pi_2 = \nu$$

$$\pi_3 = U/\ell$$

$$\pi_4 = Q/E$$

$$\pi_5 = \sigma/E$$

$$\pi_6 = \rho\,\ell^2/E\,t^2$$

Three independent scaling factors may be selected:

$$S_L = \ell_p/\ell_m$$

$$S_\rho = \rho_p/\rho_m$$

$$S_E = E_p/E_m$$

From the sixth π term:

$$t_m = \frac{1}{S_\ell}\sqrt{\frac{S_E}{S_\rho}}\, t_p$$

For the same material density and modulus in model and prototype this reduces to:

$$t_m = \frac{1}{S_\ell} t_p$$

$$\frac{t_p}{t_m} = S_t = S_L$$

A summary of other similitude requirements is given in Table 5.[8]

Table 5. Similitude Relations

Term	Symbol	Dimensions	Model and Prototype	
			Same Materials	Different Materials
Geometry	ℓ	L	S_ℓ	S_ℓ
Mass	ρ	$FL^{-4}T^2$	1	S_ρ
Modulus	E	FL^{-2}	1	S_E
Pressure	Q	FL^{-2}	1	S_E
Duration	t	T	S_ℓ	$S_\ell\sqrt{S_\rho/S_E}$
Stress	σ	FL^{-2}	1	S_E
Displacement	U	L	S_ℓ	S_ℓ
Poisson's Ratio	ν	—	1	1

REFERENCES

1. Naval Civil Engineering Laboratory. Technical Report R-564: Mix design for small-scale models of concrete structures, by D. Fuss. Port Hueneme, Calif., Feb. 1968. (AD 664956).

2. Cornell University. School of Civil Engineering. Report No. 326: Small scale direct models of reinforced and prestressed concrete structures, by H. G. Harris, G. M. Sabnis, and R. N. White. Ithaca, N. Y., Sept. 1966. (NSF Grant GP-2622)

3. Naval Civil Engineering Laboratory. Technical Report R-447: Dynamic properties of plain portland cement concrete, by W. L. Cowell. Port Hueneme, Calif., June 1966. (AD 635055).

4. Army Corps of Engineers. Engineering Manual EM-1110 345-414: Engineering and design: Design of structures to resist the effects of atomic weapons: Strength of materials and structural elements. Washington, D. C., Mar. 1957.

5. Air Force Special Weapons Center. Technical Documentary Report AFSWC-TDR-62-138: Air Force design manual; Principles and practices for design of hardened structures, by N. M. Newmark and J. D. Haltiwanger. Kirtland Air Force Base, N. M., Dec. 1962. (Contract no. AF 29(601)-2390) (AD 295408).

6. Naval Civil Engineering Laboratory. Technical Report R-331: NCEL dynamic testing machine, by W. L. Cowell. Port Hueneme, Calif., Oct. 1964. (AD 608173).

7. National Bureau of Standards. Report 1523: The effect of loading rate on the compressive strength and elastic properties of plain concrete, by D. Watstein and A. P. Boresi. Washington, D. C., Mar. 1952.

8. R. N. White. "Similitude requirements for structural models," paper presented at American Society of Civil Engineers Structural Engineering Conference, Seattle, Wash., May 8-12, 1967. (Preprint no. 469).

LIST OF SYMBOLS

d	Diameter of cylinder (in.)
E	Modulus of elasticity (psi)
F	Force
f'_c	Ultimate compressive strength (psi)
f'_{cd}	Ultimate dynamic compressive stress
L	Length
ℓ	Geometry parameter
m	Subscript, refers to model
p	Subscript, refers to prototype
Q	Loading pressure (psi)
S	Scale factor
T	Time
t	Duration of pressure (sec)
U	Displacement
ϵ	Strain (in./in.)
π	Nondimensional term
ρ	Specific mass
σ	Stress (psi)
ν	Poisson's ratio

DISTRIBUTION LIST

SNDL Code	No. of Activities	Total Copies	
—	1	20	Defense Documentation Center
FKAIC	1	10	Naval Facilities Engineering Command
FKNI	13	13	NAVFAC Engineering Field Divisions
FKN5	9	9	Public Works Centers
FA25	1	1	Public Works Center
—	15	15	RDT&E Liaison Officers at NAVFAC Engineering Field Divisions and Construction Battalion Centers
—	266	266	NCEL Special Distribution List No. 2 for persons and activities interested in reports on Atomic, Biological and Chemical Defense

Naval Civil Engineering Laboratory
DYNAMIC TESTS OF MODEL CONCRETE, by John M. Ferritto
TR-650 19 p. illus November 1969 Unclassified

1. Model concrete—dynamic properties I. YF008-08-02-126 II. DASA SC318

The objective of this project was to evaluate the dynamic properties of modeling materials. Dynamic tests were conducted on microconcrete with no. 4 and no. 30 maximum aggregate size, and gypsum concrete with no. 4 maximum aggregate size. The effects of strain rate (up to 2.5 in./in./sec) on ultimate compressive strength were obtained. The results are compared with results of dynamic tests conducted on prototype concrete by others. Microconcrete with a no. 4 maximum aggregate gives good correlation with prototype values of dynamic strength increase. The ratio of dynamic to static modulus of elasticity with increasing strain rate and dynamic strength increase factor also gives good correlation. Microconcrete with a maximum aggregate size of no. 30 gives dynamic increase factors somewhat lower than those of the prototype. The ratio of dynamic to static modulus of elasticity with increasing strain rate is greater than that of the prototype or microconcrete with no. 4 maximum aggregate. Both microconcretes experience higher strains at ultimate load than the prototype. Gypsum concrete experiences dynamic strength increase factors of approximately half those of the prototype. It may be significant that the increase in modulus of elasticity with increasing strain rate for gypsum concrete is not similar to that of prototype concrete. Strains in gypsum concrete at ultimate load are slightly higher than those for prototype concrete.

Naval Civil Engineering Laboratory
DYNAMIC TESTS OF MODEL CONCRETE, by John M. Ferritto
TR-650 19 p. illus November 1969 Unclassified

1. Model concrete—dynamic properties I. YF008-08-02-126 II. DASA SC318

The objective of this project was to evaluate the dynamic properties of modeling materials. Dynamic tests were conducted on microconcrete with no. 4 and no. 30 maximum aggregate size, and gypsum concrete with no. 4 maximum aggregate size. The effects of strain rate (up to 2.5 in./in./sec) on ultimate compressive strength were obtained. The results are compared with results of dynamic tests conducted on prototype concrete by others. Microconcrete with a no. 4 maximum aggregate gives good correlation with prototype values of dynamic strength increase. The ratio of dynamic to static modulus of elasticity with increasing strain rate and dynamic strength increase factor also gives good correlation. Microconcrete with a maximum aggregate size of no. 30 gives dynamic increase factors somewhat lower than those of the prototype. The ratio of dynamic to static modulus of elasticity with increasing strain rate is greater than that of the prototype or microconcrete with no. 4 maximum aggregate. Both microconcretes experience higher strains at ultimate load than the prototype. Gypsum concrete experiences dynamic strength increase factors of approximately half those of the prototype. It may be significant that the increase in modulus of elasticity with increasing strain rate for gypsum concrete is not similar to that of prototype concrete. Strains in gypsum concrete at ultimate load are slightly higher than those for prototype concrete.

Naval Civil Engineering Laboratory
DYNAMIC TESTS OF MODEL CONCRETE, by John M. Ferritto
TR-650 19 p. illus November 1969 Unclassified

1. Model concrete—dynamic properties I. YF008-08-02-126 II. DASA SC318

The objective of this project was to evaluate the dynamic properties of modeling materials. Dynamic tests were conducted on microconcrete with no. 4 and no. 30 maximum aggregate size, and gypsum concrete with no. 4 maximum aggregate size. The effects of strain rate (up to 2.5 in./in./sec) on ultimate compressive strength were obtained. The results are compared with results of dynamic tests conducted on prototype concrete by others. Microconcrete with a no. 4 maximum aggregate gives good correlation with prototype values of dynamic strength increase. The ratio of dynamic to static modulus of elasticity with increasing strain rate and dynamic strength increase factor also gives good correlation. Microconcrete with a maximum aggregate size of no. 30 gives dynamic increase factors somewhat lower than those of the prototype. The ratio of dynamic to static modulus of elasticity with increasing strain rate is greater than that of the prototype or microconcrete with a no. 4 maximum aggregate. Both microconcretes experience higher strains at ultimate load than the prototype. Gypsum concrete experiences dynamic strength increase factors of approximately half those of the prototype. It may be significant that the increase in modulus of elasticity with increasing strain rate for gypsum concrete is not similar to that of prototype concrete. Strains in gypsum concrete at ultimate load are slightly higher than those for prototype concrete.

Naval Civil Engineering Laboratory
DYNAMIC TESTS OF MODEL CONCRETE, by John M. Ferritto
TR-650 19 p. illus November 1969 Unclassified

1. Model concrete—dynamic properties I. YF008-08-02-126 II. DASA SC318

The objective of this project was to evaluate the dynamic properties of modeling materials. Dynamic tests were conducted on microconcrete with no. 4 and no. 30 maximum aggregate size, and gypsum concrete with no. 4 maximum aggregate size. The effects of strain rate (up to 2.5 in./in./sec) on ultimate compressive strength were obtained. The results are compared with results of dynamic tests conducted on prototype concrete by others. Microconcrete with a no. 4 maximum aggregate gives good correlation with prototype values of dynamic strength increase. The ratio of dynamic to static modulus of elasticity with increasing strain rate and dynamic strength increase factor also gives good correlation. Microconcrete with a maximum aggregate size of no. 30 gives dynamic increase factors somewhat lower than those of the prototype. The ratio of dynamic to static modulus of elasticity with increasing strain rate is greater than that of the prototype or microconcrete with no. 4 maximum aggregate. Both microconcretes experience higher strains at ultimate load than the prototype. Gypsum concrete experiences dynamic strength increase factors of approximately half those of the prototype. It may be significant that the increase in modulus of elasticity with increasing strain rate for gypsum concrete is not similar to that of prototype concrete. Strains in gypsum concrete at ultimate load are slightly higher than those for prototype concrete.

Naval Civil Engineering Laboratory
DYNAMIC TESTS OF MODEL CONCRETE, by John M. Ferritto

TR-650 19 p. illus November 1969 Unclassified

1. Model concrete—dynamic properties I. YF008-08-02-126 II. DASA SC318

The objective of this project was to evaluate the dynamic properties of modeling materials. Dynamic tests were conducted on microconcrete with no. 4 and no. 30 maximum aggregate size, and gypsum concrete with no. 4 maximum aggregate size. The effects of strain rate (up to 2.5 in./in./sec) on ultimate compressive strength were obtained. The results are compared with results of dynamic tests conducted on prototype concrete by others. Microconcrete with a no. 4 maximum aggregate gives good correlation with prototype values of dynamic strength increase. The ratio of dynamic to static modulus of elasticity with increasing strain rate and dynamic strength increase factor also gives good correlation. Microconcrete with a maximum aggregate size of no. 30 gives dynamic increase factors somewhat lower than those of the prototype. The ratio of dynamic to static modulus of elasticity with increasing strain rate is greater than that of the prototype or microconcrete with no. 4 maximum aggregate. Both microconcretes experience higher strains at ultimate load than the prototype. Gypsum concrete experiences dynamic strength increase factors of approximately half those of the prototype. It may be significant that the increase in modulus of elasticity with increasing strain rate for gypsum concrete is not similar to that of prototype concrete. Strains in gypsum concrete at ultimate load are slightly higher than those for prototype concrete.

Naval Civil Engineering Laboratory
DYNAMIC TESTS OF MODEL CONCRETE, by John M. Ferritto

TR-650 19 p. illus November 1969 Unclassified

1. Model concrete—dynamic properties I. YF008-08-02-126 II. DASA SC318

The objective of this project was to evaluate the dynamic properties of modeling materials. Dynamic tests were conducted on microconcrete with no. 4 and no. 30 maximum aggregate size, and gypsum concrete with no. 4 maximum aggregate size. The effects of strain rate (up to 2.5 in./in./sec) on ultimate compressive strength were obtained. The results are compared with results of dynamic tests conducted on prototype concrete by others. Microconcrete with a no. 4 maximum aggregate gives good correlation with prototype values of dynamic strength increase. The ratio of dynamic to static modulus of elasticity with increasing strain rate and dynamic strength increase factor also gives good correlation. Microconcrete with a maximum aggregate size of no. 30 gives dynamic increase factors somewhat lower than those of the prototype. The ratio of dynamic to static modulus of elasticity with increasing strain rate is greater than that of the prototype or microconcrete with no. 4 maximum aggregate. Both microconcretes experience higher strains at ultimate load than the prototype. Gypsum concrete experiences dynamic strength increase factors of approximately half those of the prototype. It may be significant that the increase in modulus of elasticity with increasing strain rate for gypsum concrete is not similar to that of prototype concrete. Strains in gypsum concrete at ultimate load are slightly higher than those for prototype concrete.

Naval Civil Engineering Laboratory
DYNAMIC TESTS OF MODEL CONCRETE, by John M. Ferritto

TR-650 19 p. illus November 1969 Unclassified

1. Model concrete—dynamic properties I. YF008-08-02-126 II. DASA SC318

The objective of this project was to evaluate the dynamic properties of modeling materials. Dynamic tests were conducted on microconcrete with no. 4 and no. 30 maximum aggregate size, and gypsum concrete with no. 4 maximum aggregate size. The effects of strain rate (up to 2.5 in./in./sec) on ultimate compressive strength were obtained. The results are compared with results of dynamic tests conducted on prototype concrete by others. Microconcrete with a no. 4 maximum aggregate gives good correlation with prototype values of dynamic strength increase. The ratio of dynamic to static modulus of elasticity with increasing strain rate and dynamic strength increase factor also gives good correlation. Microconcrete with a maximum aggregate size of no. 30 gives dynamic increase factors somewhat lower than those of the prototype. The ratio of dynamic to static modulus of elasticity with increasing strain rate is greater than that of the prototype or microconcrete with a no. 4 maximum aggregate. Both microconcretes experience higher strains at ultimate load than the prototype. Gypsum concrete experiences dynamic strength increase factors of approximately half those of the prototype. It may be significant that the increase in modulus of elasticity with increasing strain rate for gypsum concrete is not similar to that of prototype concrete. Strains in gypsum concrete at ultimate load are slightly higher than those for prototype concrete.

Naval Civil Engineering Laboratory
DYNAMIC TESTS OF MODEL CONCRETE, by John M. Ferritto

TR-650 19 p. illus November 1969 Unclassified

1. Model concrete—dynamic properties I. YF008-08-02-126 II. DASA SC318

The objective of this project was to evaluate the dynamic properties of modeling materials. Dynamic tests were conducted on microconcrete with no. 4 and no. 30 maximum aggregate size, and gypsum concrete with no. 4 maximum aggregate size. The effects of strain rate (up to 2.5 in./in./sec) on ultimate compressive strength were obtained. The results are compared with results of dynamic tests conducted on prototype concrete by others. Microconcrete with a no. 4 maximum aggregate gives good correlation with prototype values of dynamic strength increase. The ratio of dynamic to static modulus of elasticity with increasing strain rate and dynamic strength increase factor also gives good correlation. Microconcrete with a maximum aggregate size of no. 30 gives dynamic increase factors somewhat lower than those of the prototype. The ratio of dynamic to static modulus of elasticity with increasing strain rate is greater than that of the prototype or microconcrete with no. 4 maximum aggregate. Both microconcretes experience higher strains at ultimate load than the prototype. Gypsum concrete experiences dynamic strength increase factors of approximately half those of the prototype. It may be significant that the increase in modulus of elasticity with increasing strain rate for gypsum concrete is not similar to that of prototype concrete. Strains in gypsum concrete at ultimate load are slightly higher than those for prototype concrete.

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Naval Civil Engineering Laboratory Port Hueneme, Calif. 93041	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

DYNAMIC TESTS OF MODEL CONCRETE

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Not final; July 1967—September 1967

5. AUTHOR(S) (First name, middle initial, last name)

John M. Ferritto

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
November 1969	19	8

8a. CONTRACT OR GRANT NO. DASA SC318 b. PROJECT NO. YF008-08-02-126 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) TR-650 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Defense Atomic Support Agency Washington, D. C. 20390

13. ABSTRACT

The objective of this project was to evaluate the dynamic properties of modeling materials. Dynamic tests were conducted on microconcrete with no. 4 and no. 30 maximum aggregate size, and gypsum concrete with no. 4 maximum aggregate size. The effects of strain rate (up to 2.5 in./in./sec) on ultimate compressive strength were obtained. The results are compared with results of dynamic tests conducted on prototype concrete by others. Microconcrete with a no. 4 maximum aggregate gives good correlation with prototype values of dynamic strength increase. The ratio of dynamic to static modulus of elasticity with increasing strain rate and dynamic strength increase factor also gives good correlation. Microconcrete with a maximum aggregate size of no. 30 gives dynamic increase factors somewhat lower than those of the prototype. The ratio of dynamic to static modulus of elasticity with increasing strain rate is greater than that of the prototype or microconcrete with no. 4 maximum aggregate. Both microconcretes experience higher strains at ultimate load than the prototype. Gypsum concrete experiences dynamic strength increase factors of approximately half those of the prototype. It may be significant that the increase in modulus of elasticity with increasing strain rate for gypsum concrete is not similar to that of prototype concrete. Strains in gypsum concrete at ultimate load are slightly higher than those for prototype concrete.

Unclassified
Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Model concrete						
Microconcrete						
Gypsum concrete						
Prototype concrete						
Dynamic properties						
Strain						
Stress						
Compressive strength						
Modulus of elasticity						

DD FORM 1 NOV 65 1473 (BACK)
(PAGE 2)

Unclassified
Security Classification