Komar University Of Science And Technology (KUST)

Department of Civil Engineering

Laboratory Manual for Testing Material

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Prepared By

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PREFACE AND ACKNOWLEDGEMENT

While designing a structure, engineer assumes certain value of strength for each of material being used therein. When the structure is being constructed, it is the bounden duty of the field engineers to get the same validated by regular testing of material. The quality of materials used in any infrastructure does play a vital role with regard to its ultimate strength and durability in the long run. Hence, the materials need to be tested according to certain standard procedures developed by ASTM to give a clear picture of material strength. The manual of testing materials is an attempt to bring together the standard test procedures for materials frequently used in the civil engineering infrastructure. It is hoped that this will be a helpful guide to the field engineers.

This manual was completed with support of KUST administration, faculty, and staff members. Therefore, I am thankful for their efforts.

CONTENTS

1. INTRODUCTION

In this course we are seeking to understand material properties through laboratory experiments. Usually the class is divided into groups. Each group will do a different experiment every week until all the required experiments are completed. Each instructor will indicate the experiments to be conducted and advise on the nature of the lab report and time of submission. However, a typical format for a lab report is included below. It is important that all the information necessary to complete the lab report is obtained before students leave the lab.

2. LAB REPORT REQUIREMENTS

2.1 GENERAL

The following suggestions should be helpful.

• Avoid personal pronouns.

• If you quote from a text, identify the text.

• View this report as though you were in industry and writing for your boss. Hence sloppiness will not be accepted.

2.2 FORMAT

2.2.1 TITLE

There should be a Title Page with title, authors, group number, date, for whom report was written.

2.2.2 ABSTRACT

It should be approximately half a typed page in length. An abstract should tell: What was done briefly how experiment was conducted to satisfy objectives and what the major conclusions or representative results are.

2.2.3 TABLE OF CONTENTS

Must have page numbers of different sections in the report..

2.2.4 INTRODUCTION

A. Establish general interest in the subject.

B. Establish specific interest and justification for conducting this investigation leading to a statement of the specific objective(s).

C. Introduce the report itself. That is, tell the reader how the report is organized and what to expect.

2.2.5 THEORY

A. Present theoretical basis for the experiment or investigation.

B. Present equations used with clear indication of which variables were measured and which is calculated.

2.2.6 EXPERIMENTAL APPARATUS

A. Diagram of the test set-up illustrating the general relationships among the various components of the system and the locations at which the measurements were taken.

B. Instrumentation (measurement systems) that was used should be stated and related to the measurement locations on the diagram (with a statement of the uncertainty associated with each measurement system).

2.2.7 RESULTS

Introduce results; that is, explain what is being presented. Don't just include the plots, charts, etc., without any explanation. Tables and figures must be self-contained. They must be numbered and with a caption. Thus the reader can tell what a table or figure means without having to look through the text.

2.2.8 DISCUSSION OF RESULTS

A. Interpret and explain results

B. Point out most important results, even if the results as presented seem obvious *to* you, you want *to* be sure your reader notices the most important features and trends, etc. State what you think the results show, prove, demonstrate or illustrate.

2.2.9 CONCLUSION

Summarize your findings; that is, itemize the most important things that you found out, measured, observed. Anything that could be preceded by "It was found that" or "It was discovered that" is a finding, not a conclusion. Remember conclusions are generalizations based on results of a specific investigation.

2.2.10 BIBLIOGRAPHY

Number your references in order.

2.2.11 APPENDICES

Extensive pages of data can go in Appendix.

3 SAFETY

1. Follow all safety instructions given in the class and in the laboratories.
2. Charpy machine can be lethal. Never leave the hammer in the up position until ready to break a specimen.
3. Furnaces. Be careful in touching and handling specimens. Use tongs for placing specimens in the furnace and removing them. Most specimens can be quenched in water after removal from furnace.
4. Tensile Testing. During the tensile test pieces can fly out during fracture.
5. Use safety eye shield when grinding specimens.
6. Do not remove specimens from abrasive cut-off machine until the wheel has stopped.
7. NO eating or drinking in the lab.

3.1 SAFETY IN THE LABORATORY

All students must read and understand the information in this document with regard to laboratory safety and emergency procedures prior to the first laboratory session. **Your personal laboratory safety depends mostly on YOU**. Effort has been made to address situations that may pose a hazard in the lab but the information and instructions provided cannot be considered all-inclusive. Students must adhere to written and verbal safety instructions throughout the academic term. Since additional instructions may be given at the beginning of laboratory sessions, it is important that all students arrive at each session on time. With good judgment, the chance of an accident in this course is very small. Nevertheless, research and teaching workplaces (labs, shops, etc.) are full of potential hazards that can cause serious injury and or damage to the equipment. Working alone and unsupervised in laboratories is forbidden if you are working with hazardous substances or equipment. With prior approval, at least two people should be present so that one can shut down equipment and call for help in the event of an emergency. Safety training and/or information should be provided by a faculty member, teaching assistant, lab safety contact, or staff member at the beginning of a new assignment or when a new hazard is introduced into the workplace.

3.2 EMERGENCY RESPONSE

1. It is your responsibility to read safety and fire alarm posters and follow the instructions during an emergency
2. Know the location of the fire extinguisher, eye wash, and safety shower in your lab and know how to use them.
3. Notify your instructor immediately after any injury, fire or explosion, or spill.
4. Know the building evacuation procedures.

3.2.1 Common Sense

Good common sense is needed for safety in a laboratory. It is expected that each student will work in a responsible manner and exercise good judgment and common sense. If at any time you are not sure how to handle a particular situation, ask your Teaching Assistant or Instructor for advice. **DO NOT TOUCH ANYTHING WITH WHICH YOU ARE NOT COMPLETELY FAMILIAR**!!! It is always better to ask questions than to risk harm to yourself or damage to the equipment.

3.3 PERSONAL AND GENERAL LABORATORY SAFETY

1. Never eat, drink, or smoke while working in the laboratory.
2. Read labels carefully.
3. Do not use any equipment unless you are trained and approved as a user by your supervisor.
4. Wear safety glasses or face shields when working with hazardous materials and/or equipment.
5. Wear gloves when using any hazardous or toxic agent.
6. Clothing: When handling dangerous substances, wear gloves, laboratory coats, and safety shield or glasses. Shorts and sandals should not be worn in the lab at any time. Shoes are required when working in the machine shops.
7. If you have long hair or loose clothes, make sure it is tied back or confined.
8. Keep the work area clear of all materials except those needed for your work. Coats should be hung in the hall or placed in a locker. Extra books, purses, etc. should be kept away from equipment, that requires air flow or ventilation to prevent overheating.
9. Disposal - Students are responsible for the proper disposal of used material if any in appropriate containers.

10. Equipment Failure - If a piece of equipment fails while being used, report it immediately to your lab assistant or tutor. Never try to fix the problem yourself because you could harm yourself and others.

11. If leaving a lab unattended, turn off all ignition sources and lock the doors.

12. Never pipette anything by mouth.

13. Clean up your work area before leaving.

14. Wash hands before leaving the lab and before eating.

3.4 ELECTRICAL SAFETY

1. Obtain permission before operating any high voltage equipment.

2. Maintain an unobstructed access to all electrical panels.

3. Wiring or other electrical modifications must be referred to the Electronics Shop or the Building Coordinator.

4. Avoid using extension cords whenever possible. If you must use one, obtain a heavy- duty one that is electrically grounded, with its own fuse, and install it safely. Extension cords should not go under doors, across aisles, be hung from the ceiling, or plugged into other extension cords.

5. Never, ever modify, attach or otherwise change any high voltage equipment.

6. Always make sure all capacitors are discharged (using a grounded cable with an insulating handle) before touching high voltage leads or the "inside" of any equipment even after it has been turned off. Capacitors can hold charge for many hours after the equipment has been turned off.

7. When you are adjusting any high voltage equipment or a laser which is powered with a high voltage supply, USE ONLY ONE HAND. Your other hand is best placed in a pocket or behind your back. This procedure eliminates the possibility of an accident where high voltage current flows up one arm, through your chest, and down the other arm.

3.5 MECHANICAL SAFETY

1. When using compressed air, use only approved nozzles and never direct the air towards any person.

2. Guards on machinery must be in place during operation.

3. Exercise care when working with or near hydraulically- or pneumatically driven equipment. Sudden or unexpected motion can inflict serious injury.

3.6 CHEMICAL SAFETY

1. Treat every chemical as if it were hazardous.
2. Make sure all chemicals are clearly and currently labeled with the substance name, concentration, date, and name of the individual responsible.
3. Never return chemicals to reagent bottles. (Try for the correct amount and share any excess.)
4. Comply with fire regulations concerning storage quantities, types of approved containers and cabinets, proper labeling, etc. If uncertain about regulations, contact the building coordinator.
5. Use volatile and flammable compounds only in a fume hood. Procedures that produce aerosols should be performed in a hood to prevent inhalation of hazardous material.
6. Never allow a solvent to come in contact with your skin. Always use gloves.
7. Never "smell" a solvent!! Read the label on the solvent bottle to identify its contents.
8. Dispose of waste and broken glassware in proper containers.
9. Clean up spills immediately.
10. Do not store food in laboratories.

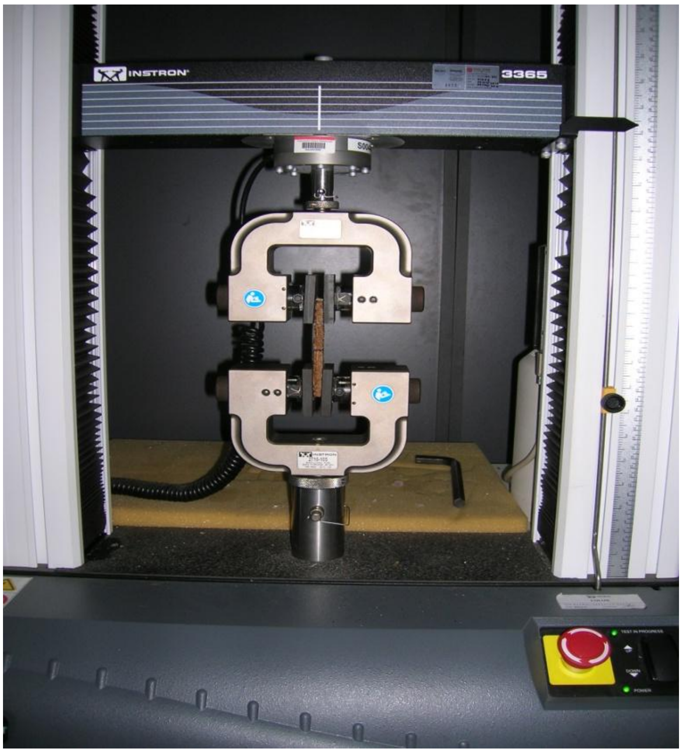
3.7 LASERS SAFETY

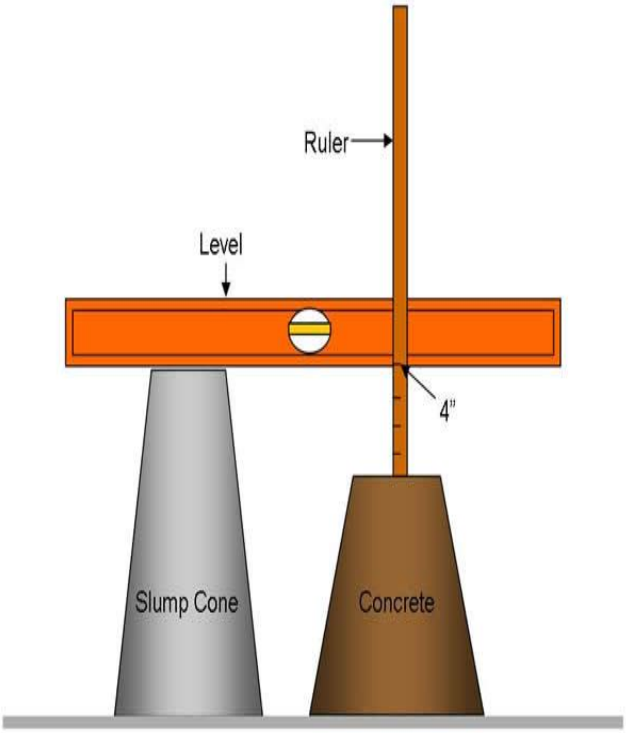
1. NEVER, EVER LOOK INTO ANY LASER BEAM, no matter how low power or "eye safe" you may think it is.
2. Always wear safety goggles if instructed by your Instructor or Teaching Assistant.
3. The most common injury using lasers is an eye injury resulting from scattered laser light reflected off of mountings, sides of mirrors or from the "shiny" surface of an optical table. The best way to avoid these injuries is to always wear your goggles and NEVER LOWER YOUR HEAD TO THE LEVEL OF THE LASER BEAM! The laser beam should always be at or below chest level.
4. Always use "beam stops" to intercept laser beams. Never allow them to propagate into the laboratory. Never walk through a laser beam. Some laser beams of only a few watts can burn a hole through a shirt in only a few seconds.
5. If you suspect that you have suffered an eye injury, notify your instructor or teaching assistant IMMEDIATELY! Your ability to recover from an eye injury decreases the longer you wait for treatment.

3.8 ADDITIONAL SAFETY GUIDELINES

- Never do unauthorized experiments.
- Never work alone in laboratory.
- Keep your lab space clean and organized.
- Do not leave an on-going experiment unattended.
- Always inform your instructor if you break a thermometer. Do not clean mercury yourself!!
- Never taste anything. Never pipette by mouth; use a bulb.
- Never use open flames in laboratory unless instructed by TA.
- Check your glassware for cracks and chips each time you use it. Cracks could cause the glassware to fail during use and cause serious injury to you or lab mates.
- Maintain unobstructed access to all exits, fire extinguishers, electrical panels, emergency showers, and eye washes.
- Do not use corridors for storage or work areas.
- Do not store heavy items above table height. Any overhead storage of supplies on top of cabinets should be limited to lightweight items only. Also, remember that a 36" diameter area around all fire sprinkler heads must be kept clear at all times.
- Areas containing lasers, biohazards, radioisotopes, and carcinogens should be posted accordingly. However, do not post areas unnecessarily and be sure that the labels are removed when the hazards are no longer present.
- Be careful when lifting heavy objects. Only shop staff may operate forklifts or cranes.
- Clean your lab bench and equipment, and lock the door before you leave the laboratory.

4. Laboratory Experiments





4.1 Experiment No.1: Tensile Testing Of Steel [ASTM E8]

Introduction:

The most common material in construction besides concrete is steel. Concrete, though it has a high compressive strength, its tensile strength is usually much lower and mounts up to 8 – 12 % of its compressive strength. Steel, therefore, is used in concrete structural elements to bare tensile loads and bending moments. The major components of steel are Iron and carbon which ranges between 0.01 and 1 percent. Sulfur, phosphorus, manganese, silicon and as much as 20 other alloys are present in steel and are added in various quantities to steel during its manufacturing process depending on the desired hardness, toughness and tensile strength of steel.1 Reinforcing steel bars are usually manufactured in 3 different forms:

- Plain bars
- Deformed bars
- Plain & deformed wires

Figure 1: plain Bars

Figure 2: Deformed Bars

Figure 3: Plain & Deformed Bars

The deformation in deformed steel bars is intended to increase the bonding between steel and concrete and to prevent slippage of the steel reinforcement bars. Steel reinforcement bars are produced mainly with four different yield strengths, shown in the table below. The grade of steel indicates its yield strength in Ksi.

Type	σ_{yield} (psi)	σ_{yield} (MPa)	Grade
Type1	40,000	300	40
Type 2	50,000	350	50
Type 3	60,000	400	60
Type 4	75,000	500	75

Table 1: Reinforcement Steel Strength

Objectives

The objective of this lab experiments is to incrementally load a steel bar till failure, while recording the value of the load and the change in length of the steel bar at each stage. Then based on the collected data, determine:

- Modulus of Elasticity of Steel, E_{steel} & Compare it to the theoretical value.
- Yield strength of Steel, σ_{yield}
- Ultimate strength of steel, $\sigma_{Ultimate}$
- Plot Stress Vs Strain Curve for steel

Definitions

-Yield Point: The Point at which an increase in strain occurs without an increase in the stress is defined as the yield point. Stress at this point is defined as the steel yield stress.

Equipment

- Universal Testing Machine
- Dial Gauge / Extensometer

Figure 4: Tinius Olsen Universal Testing Machine

Figure 5: Dial Gauge

Procedure

1. Load a Steel bar into the machine, with a 6” length of steel between the testing machine clamps.

2. Mount the dial gauge and reset to Zero

3. Apply load with in stages, starting with 250 lb and with increments of 250 lb

4. At each load stage record the applied load and the Change in bar length (read from gauge).

5. Keep incrementing the load till failure.

P.s.: At failure notice the tip & cone failure mode of the steel bar.

Equations

$$\sigma = \frac{P}{A} \qquad \varepsilon = \frac{\delta}{L} \qquad E = \frac{\sigma}{\varepsilon} = \frac{\Delta\sigma}{\Delta\varepsilon} \qquad A = \frac{\pi d^2}{4} \qquad L = 6''$$

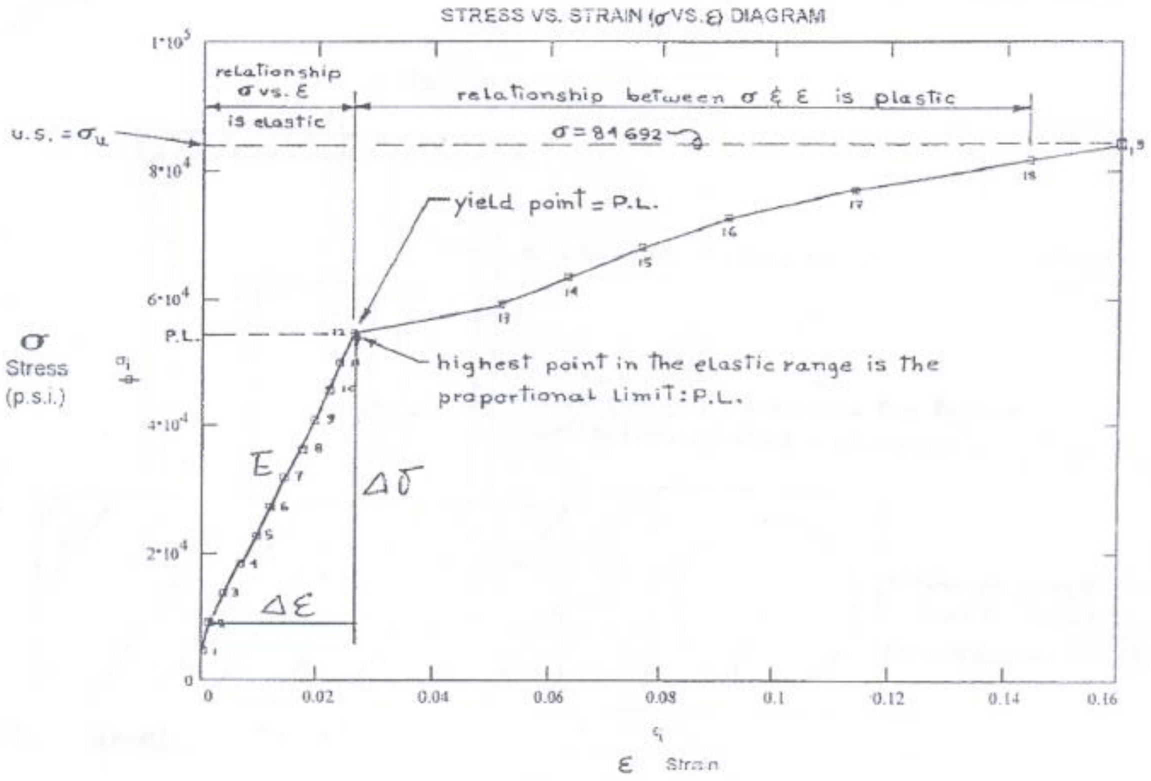
$$E_{Experimental} = \frac{\Delta\sigma}{\Delta\varepsilon}(Slope) \qquad or \qquad E_{Experimental} = E_{ave}$$

$$E_{ave} = \frac{E_1 + E_2 + E_3 + \ldots\ldots\ldots + E_m}{m}$$

$$E_{Theoretical,Steel} = 29\,x10^6\ psi$$

$$\%\ Error = \frac{\left|E_{Experimental} - E_{Theoretical}\right|}{E_{Theoretical}}\ x\,100\%$$

Typical Stress-Strain Curve

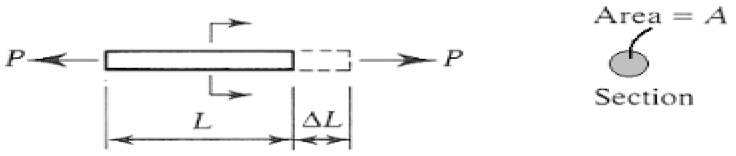


Calculation Sheet

P (lb)	δ (in)	σ (psi)	ε	E (psi)
250	δ_1	σ_1	ε_1	E_1
500	δ_2	σ_2	ε_2	E_2
750	δ_3	σ_3	ε_3	E_3
….	….	….	….	….
….	….	….	….	….
….	….	….	….	….
….	….	….	….	….
P_m	δ_m	(PL) σ_m	ε_m	E_m
….	….	….	….	N/A
….	….	….	….	N/A
….	….	….	….	N/A
P_{n-1}	δ_{n-1}	σ_{n-1}	ε_{n-1}	N/A
P_n (P_{max})	N/A	σ_n (σ_{max})	N/A	N/A

Discussion

Possible source of error: Slipping of the steel at the testing machine grips



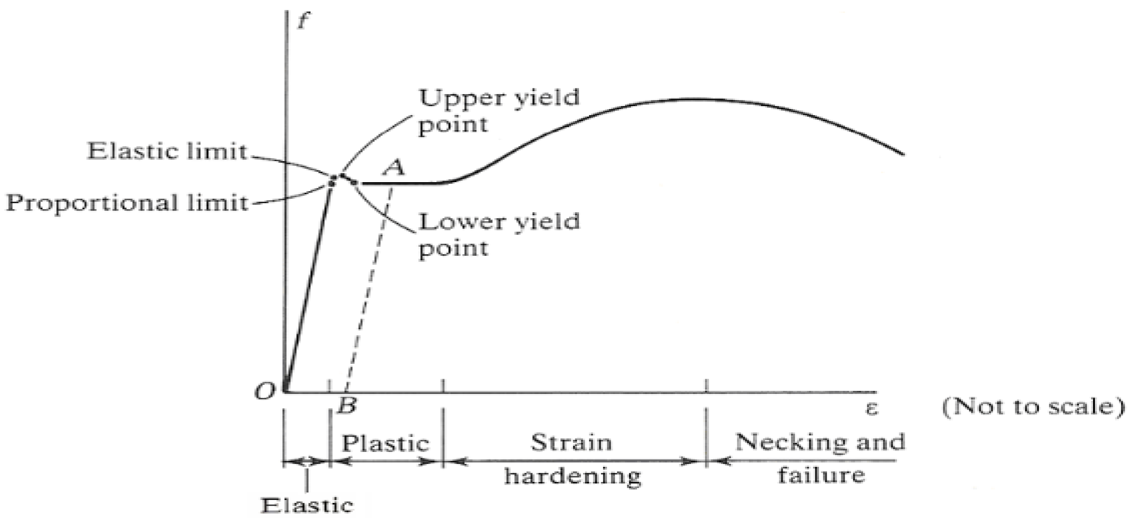


Figure 7. Theoretical Stress-Strain diagram .

4.2 Experiment No.2: Sieve Analysis of aggregates [ASTM C 136-84a]

Scope:

This method covers the determination of the particle size distribution the fine and coarse aggregate by sieving.

Materials:

1. The weight of test sample of fine aggregate shall be, after drying, approximately (500 gm).
2. The weight of test sample of coarse aggregate shall conform with the following:

N.M.S (mm)	Minimum Weight (kg)
9.5	1
12.5	2
19	5
25	10
37.5	15

Apparatus:

1. Balance: For fine aggregate accurate for 0.5gm. For coarse aggregate accurate for 0.5gm.
2. Containers to carry the sample.
3. Oven.
4. Mechanical Sieve shaker.
5. Two sets of sieve:-For fine aggregate [No.4 , No.8, No.16 , No.30 , No.50, No.100]
   For coarse aggregate [37.5mm , 19mm ,9.5mm, No.4 , No.8]

In addition to a pan and a cover for each set.

Procedure:

1- Put the sample in the oven at 110°C.

2-Determine the empty weight for each sieve and record.

3-Nest the sieve in order of decreasing size of opening from top to bottom place the sample on the top sieve.

4- Agitate (shake) the sieve by placing the set on the mechanical shaker for 10min.

5- Open the set of sieve carefully so that no loosing of materials is expected.

6-Weigh each sieve with the residue record its weight.

7- Tabulate your data in a suitable shape.

8. Make sure that the summation of the residue weights equals to the original sample weight with a difference not more than 1% of the original weight.

9-The table should contain:-

No. of sieve	Sieve empty Wt	Sieve +residue Wt	Residue Wt	Residue %	% Cum Residue	% Passing

10- Fineness Modulus for fine aggregate can be determined as: -

$$F.M. = \frac{\Sigma \text{ cumulative residue percentage}}{100}$$

It must be within-(2.6 - 3.1) for sand.

Notes:

1-The sieves dimensions are:

No. of sieve	100	50	30	16	8	4	3/8"	1/2"	3/4"	1"	1.5"
Size of opening (mm)	0.150	0.3	0.6	1.18	2.36	4.75	9.5	12.5	19	25.4	37.5

2- The results must be companied with ASTM Specification [C33-99a]

- For Fine aggregate:

Sieve No.	Sieve size	% Passing
3/4"	1.9mm	100
No.4	4.75mm	95-100
No.8	2.36mm	80-100
No.16	1.18mm	50-85
No.30	0.600mm	25-60
No.50	0.3mm	10-30
No.100	0.15mm	2-10

Figure 8 The Mechanical sieve Shaker

4.3 Experiment No.3:The Slump of Cement Concrete [ASTM C143-89a]

Scope:

This test method is used to determine the slump of freshly mixed concrete, which is an approximate measure of consistency. The test may be done in the laboratory and in field.

Apparatus:

1- Weights and weighing device.

2- Tools and containers for mixing, or concrete mixer .

3- Tamper (16 mm in diameter and 600 mm length)

4- Ruler

5- Slump cone which has the shape of a frustum of a cone with the following dimensions:

Base diameter 20 cm

Top diameter 10 cm

Height 30 cm

Materials thickness at least 1.6 mm

Procedure:

1- Prepare a clean, wide, flat mixing pan.

2-Place the dampened slump cone on one side of the pan. It shall be held firmly in place during filling by the operator standing on the two foot pieces.

3- Place the newly mixed concrete (prepared as in test No. 3) in three layers, each approximately one third the volume of the mold.

4- In placing each scoopful of concrete, move the scoop around the top edge of the mold as the concrete slides from it, in order to ensure symmetrical distribution of concrete within the mold.

5- Rod each layer with 25 strokes of the tamper, distribute the strokes in a uniform manner over the cross section of the mold, each stroke just penetrating into the underlying layer.

6- For the bottom layer this will necessitate inclining the rod slightly and making approximately half of the strokes spirally toward the center. Rod the bottom layer throughout its depth.

7- In filling and rodding the top layer, heap the concrete above the mold before rodding is started.

8- After rodding the top layer, strike off the surface of the concrete with a trowel, leaving the mold exactly filled.

9- While filling and rodding, be sure that the mold is firmly fixed by feet and can't move.

10- Clean the surface of the base outside the cone of any excess concrete. Then immediately remove the mold from the concrete by raising it slowly in a vertical direction.

11-Measure the slump immediately by determining the difference between the height of the mold and the height of the vertical axis (not the maximum height) of the specimen.

12- Clean the mold and the container thoroughly immediately after using.

13-If the pile topples [when raising the mold out of concrete] sideways, it indicates that the materials have not been uniformly distributed in the mold and the test should be remade.

Figure 9 Measuring the slump.

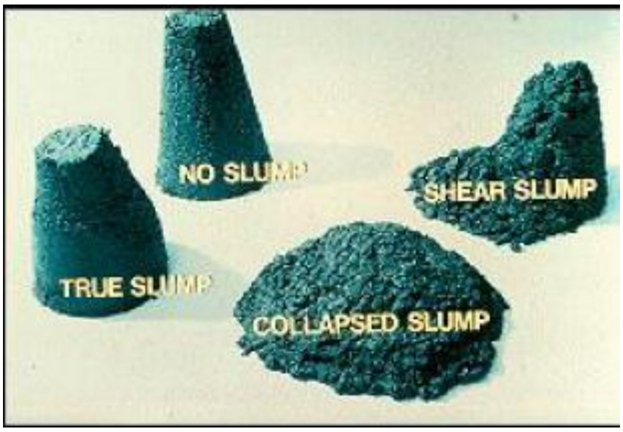


Figure 10 Different possible slump test results.

4.4 Experiment No.4: “The Compressive Strength of Cubic Concrete Specimens” [BS 1881: Part 116: 1983]

Scope:

The test method covers determination of compressive strength of cubic concrete specimens. It consists of applying a compressive axial load to molded cubes at a rate which is within a prescribed range until failure occurs. The compressive strength is calculated by dividing the maximum load attained during the test by the cross sectional area of the specimen.

Apparatus:

1- Weights and weighing device.

2- Tools and containers for mixing.

3- Tamper (square in cross section)

4- Testing machine.

5- Three cubes (150 mm side)

Procedure:

1- Prepare a concrete mix as mentioned in (test No. 3) with the proportions suggested Such as: 1: 2: 3 with w/c = 55% by mechanical mixer.

2- Prepare three testing cubes; make sure that they are clean and greased or oiled thinly.

3-Metal molds should be sealed to their base plates to prevent loss of water.

4-Fill the cubes in three layers, tamping each layer with (35) strokes using a tamper, square in cross-section with 2.54 cm side and 38.1 cm length, weighing 1.818 kg.

5- While filling the molds, occasionally stir and scrape together the concrete remaining in the mixer to keep the materials from separating.

6- Fill the molds completely, smooth off the tops evenly, and clean up any concrete outside the cubes.

7- Mark the specimens by a slip of paper on which is written the date and the Specimen identification. Leave the specimens in the curing room for 24 hours.

8- After that open the molds and immerse the concrete cubes in a water basin for 7 days.

9- Before testing, ensure that all testing machine bearing surfaces are wiped clean.

10-Carefully center the cube on the lower platen and ensure that the load will be applied to two opposite cast faces of the cube.

11-Without shock, apply and increase the load continuously at a nominal rate within the range of (0.2 N/mm2.s to 0.4 N/mm2.s) until no greater load can be sustained. On manually controlled machines, as failure is approached, the loading rate will decrease, at this stage operate the controls to maintain, as far as possible, the specified loading rate. Record the maximum load applied to each cube.

Note:

When the cubes are surface dry, or have not been cured in water, immerse them in water, for a minimum of 5 minutes, before testing. They must be tested while they are still wet.

Type of failure

Record any unusual feature in the type of failure. Refer to fig. ( ) for examples of satisfactory failure and to fig. ( ) for examples of some unsatisfactory failures.

Note: Unsatisfactory failures are usually caused by insufficient attention to the details of making and testing specimens, such as bad molds, bad made specimens or mis placement of cubes in the testing machine or machine fault.

Calculations

Calculate the cross-sectional area of the cube face from the checked nominal dimensions.

Calculate the compressive strength of each cube by dividing the maximum load by the cross-sectional area.

Calculate the average for the three cubes.

Figure 11 Satisfactory failure

Note: All four exposed faces are cracked approximately equally.

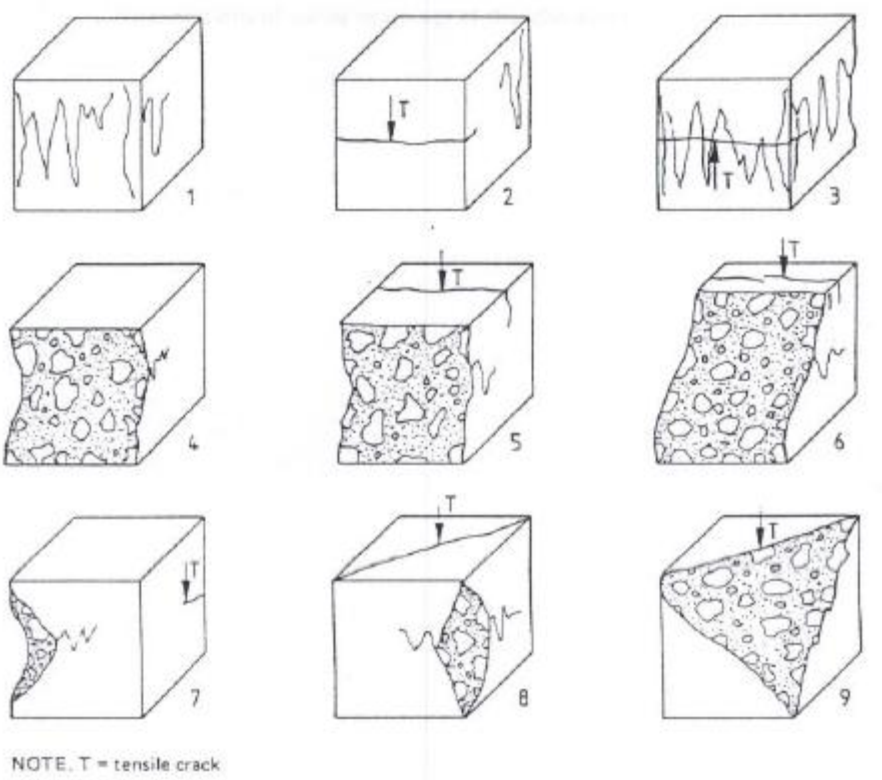


Figure 12 Unsatisfactory failure

Figure 13 The compression machine.

5. REFERENCES

1- American Society for Testing and Materials (1997). Annual Book of ASTM Standards, Vol. 04.08, Conshohocken, Pa.

2- Khanna, S.K. and C.E.G Justo, Highway Materials Testing Laboratory Manual, Nem Chand Bros. Roorkee.

3- Sood H., Mittal L.N and Kulkarni P.D., “Laboratory Manual on Concrete Technology”, CBS Publishers & Distributors Pvt. Ltd