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Research paper



Effect of Loading Speed on Direct and Indirect Tensile Strength of Rock and Concrete

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Abstract

The trial work and numerical demonstrating were considered to examine the impacts of strain rate in the rigidity of rocks and cement in the research facility. Three trial of the exploratory work were considered, guide pressure test to get immediate elastic outcomes, Brazilian split test, and three-point flexural stacking test, to get roundabout ductile outcomes. While the numerical displaying utilizing limited component programming ABAQUS, to examined numerically the examples of 48 research facility tests. Immediate and roundabout rigidity tests, arranged two kinds of totals (0-6) mm and (0-12) mm for solid examples and shake tests (sedimentary and changeable) utilizing distinctive strain rates (10-2, 10-4, 10-5)s-1. The test and numerical outcomes demonstrated that strain rate articulated impacts on the elasticity of shake and cement and impacts are reliant upon the kind of shake and cement consolidated materials, and the broke surfaces of the considerable number of examples in all tests turned out to be more straightened with the expanding strain rate. The numerical and test results demonstrate a decent assention. The surmised (11%-18%) contrast between the tests results acquired through trial and numerical demonstrating might be ascribed to the disentanglement utilized in the numerical displaying.

Keywords: *Direct and Indirect Tensile Strength; Marble; Mortar, Shotcrete; Strain rate; Travertine*

1. Introduction

Fragile material like shakes and cement are very little in pressure than in pressure. Depicting the elasticity of rocks and cement thus is of incredible significance in many building applications, for example, square buckle mining, burrowing, shake inclines and in addition shake establishments following blast or seismic tremor, covers, fracking. So it was expanding interest for underground framework. Therefore, the capacity to foresee the quality conduct of shake materials is essential for the plan build since it permits him a superior energy about the issue close by, illuminates the impact of various factors, and gives a gauge of the structure parameters, and one of the structure parameters is quality under various strain rates [1]. For that, the impact of various strain rates on the mechanical reaction of rocks and cement are exceptionally fundamental to understanding material disappointment under extraordinary stacking conditions and furthermore, assessing the harm attributes of shake structures. Where every single related paper of specialists and late improvements which keen on the impact of various strain rates on immediate and circuitous elasticity of rocks and solid materials were perused. For instance, [2], [3], [4], [5], [6], [7], [8], examined and assessed the impact of the stacking rate on quality for shake and cement. [9], [10], considered impacts of stacking rate on shake break.

Then again, on account of the troubles related with end connections in leading direct strain tests when attempting to apply an unadulterated pressure compel free of any capriciousness and furthermore the staggering expense of giving the correct strategy to this testing, it prompted abstain from playing out a direct elastic test. Where elective tests, for example, flexural quality test and Brazilian split test were utilized in the assurance of elasticity of rocks[11]. Therefore, coordinate and furthermore circuitous malleable test strategies were utilized in this paper, to think about the quality and distortion properties of shake and solid material under various strain rates, which are viewed as critical parameters in plan.

2. Apparatus and Specimen preparation

Immediate and roundabout elasticity tests and uniaxial pressure quality tests were completed utilizing a stacking outline made by DARTEC-9600 company by unbending two smooth segment development. The machine is finished with a heap cell, stroke transducer, and servo valve. Limit around 1200 KN for pressure, 2000 KN for pressure, stack cell around 2000 KN pressure just, stroke transducer go 450 mm and servo-valve measure 20 liters/minute as represented figure 1(a). Horizontal relocation was estimated utilizing a direct factor differential transducer - LVDT (Stroke Transducer) in the DARTEC-9600. The strain was estimated utilizing electrical obstruction strain measures. Three LVDT established at about mid-stature on every example was utilized for uniaxial pressure quality trial of both shake and cement to estimating sidelong strain by utilizing information lumberjack display DL16DYST as appeared in figure 1(b).

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(a) (b)

Fig. 1: (a) The DARTEC-9600 electro-hydraulic servo and (b) Linear Variable Differential Transformer device model DL16DYST

The heap was connected at three distinctive strain rates (10-2, 10-4 and 10-5 s-1), which was controlled via consequently framework stacking rates. The test spans relatively comparing to each strain rate were around 3 sec, 10 min, and 17 min. Coordinate pressure, Brazilian, Flexural and Uniaxial pressure tests at room temperature and at strain rates for rocks and cement for any trial of the previously mentioned were done, as outlined in figure 2. The tests were directed in three gatherings, in particular strain rates were 10-5, 10-4 and 10-2 s-1. There were two examples of rocks (marble and travertine rocks) thus concrete (shotcrete blend and mortar blend) in each gathering, as per table 1. An aggregate of 24 examples were tried of marble shakes thus likewise travertine rocks and a similar thing for sorts of solid blend. Amid the way toward stacking, removal was recorded by LVDT in the meantime for a uniaxial pressure test, as appeared in figure 2 (d).

Table 1: Test scheme for rocks (marble and travertine) and concrete (shotcrete mix and mortar mix)

strain rate (s^{-1})		Quantity of specimen			Specimen size (Diameter × Length) mm		
		10^{-5}	10^{-4}	10^{-2}	rock	mortar	shotcrete
Test name	Direct tension	2	2	2	54×110	68×141	100×200
	Brazilian split	2	2	2			
	Flexural	2	2	2			
	Uniaxial compression	2	2	2			



(a) (b) (c) (d)

Fig. 2: Rock and concrete specimens in testing machine: (a) direct tension; (b) Brazilian splitting; (c) three-point loading; (d) uniaxial compressive strength

2.1. Rock specimen

Samples of Mahallati marble and travertine were prepared for testing, in Iran. The specimens could not be cut to the same lengths due to the limitations of the length of the cores. However, the length to diameter ratio was controlled in the range of 2.0–2.15 to approximately meet [12] and ISRM Suggested Method (ISRM 1979).

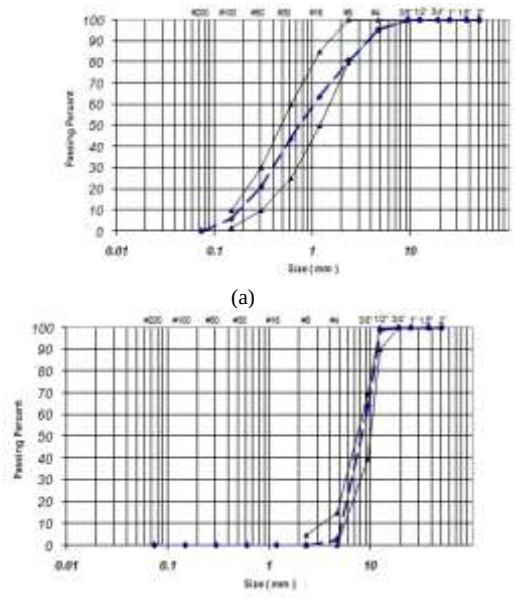
2.2. Concrete specimen

Two cement blends (first shotcrete blend and second mortar blend) were researched. The extent of crude materials and blend structure factors are condensed in Table 2. Ostensible (0-12) mm coarse totals and (0-6) mm fine totals were utilized to plan shotcrete cement and mortar for the exploratory tests, separately. Rakish smashed total and locally accessible waterway sand with a fineness modulus of 2.88 were utilized as coarse totals and fine totals separately. The blending techniques for the shotcrete and mortar materials were comparative. The sizes of both shotcrete and mortar were 0.02 and 0.007 m3 utilized in the tests individually.

Table 2: Mix proportion of Mortar and shotcrete

	Cement	Fine Aggregate	Coarse Aggregate	Water	superplasticizer	Max. size mm
Gradation of shotcrete (kg/m^3)	6	24.5	14	2.4	0.03	12
Gradation of Mortar (kg/m^3)	393	11.665	---	196.5	0.03	6

Strainer investigations were performed on totals utilized in both cement blends. As per [13], [14], [15], grain estimate dissemination of coarse and fine total are represented in figure 4 (an) and (b). The explicit gravities of the fine and coarse totals were 2.50 and 2.55, individually. The coarse total and sand were air dried before blending.



(a) (b)

Fig. 4: graph of logarithmic sieve size vs. passing percent of (a) sand. (b) gravel.

The folios (bond) and the fluid segment (water or totals) were blended in an ordinary skillet blender for 5 min. The bond and totals were dry blended for 3 min. Water was included and wet

blending was completed for 4 min. With the end goal to enhance the usefulness, super plasticizer was added to both blends. The blend was then filled shape in three equivalent layers. Each layer was vibrated for 10– 20 sec on a vibration table. The shotcrete and mortar examples were restored by [16] necessities (ASTM, 2007a). Following throwing, the examples were secured with a plastic film to keep the dampness from dissipating. Examples were de-shaped after 24 h and sodden relieved for 28 days. Following 28 days of relieving, the examples were expelled from the restoring tank. In this paper, type 2 Tehran Portland concrete was chosen for both two blends.

For direct malleable tests, reinforced steel end plates were utilized to apply a fast pliable load to the example, as appeared in figure 2(a). The two sorts of steel end plate having a width of 95 mm, 130 mm and a thickness of 16 mm to use in this test. An epoxy glue (UHU In addition to End quick 300) was utilized to stick the steel end plate to the example. The cement properties utilized are as per table 3. An exceptionally planned jolt was utilized to interface between the testing machine and end plate to kill any twisting minute amid testing. The pliable example was associated with the end plate and in this manner joined to the testing machine.

Table 3: Specifications UHU plus End fest 300

Tensile strength (MPa)	Time of sclerosis (min)	Temperature (C•)
12	720	20
18	180	40
20	45	70
25	10	100
30	5	180

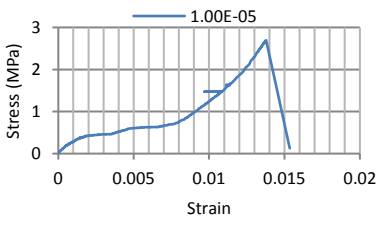
3. Results and Discussion

3.1. Experimental Work Result

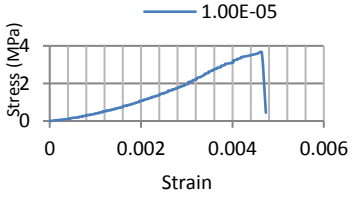
The experimental work results involve tables and curves for the results of the tested materials such as marble, travertine, mortar, and shotcrete. The tabulation of results and curves styling is similar to the approach of former researchers [1], [4], [7], [8], [17], [18], [19], [20], [21], [22], [23]. Table 4 summarized the experimental work results for the specimens of rocks (marble and travertine) and concrete (mortar and shotcrete) for different strain rate (10^{-5}, 10^{-4} and 10^{-2}) s^{-1}. Typical test results of marble at strain rate 10^{-5} s^{-1} are shown in figure 5.

Table 4: Experimental results for all rock and concrete specimens obtained by different test methods

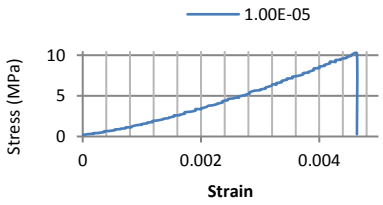
Test name		Serial #	Number of samples	Strain rate(mm×s^{-1})	Types of Rock		Types of concrete			
					Marble	Travertine	Mortar		Shotcrete	
					Average strength (MPa)	Average strength (MPa)	Strain rate (mm×s^{-1})	Average strength (MPa)	Strain rate (mm×s^{-1})	Average strength (MPa)
Direct tension		1	1	115×10^{-5}	2.64	6.25	142×10^{-5}	2.42	200×10^{-5}	2.41
		2	2							
		3	1	114×10^{-4}	3.09	7.19	142×10^{-4}	2.98	200×10^{-4}	2.67
		4	2							
		5	1	115×10^{-2}	3.30	6.97	142×10^{-2}	3.17	200×10^{-2}	2.86
		6	2							
Indirect tension	Three-point loading	7	1	11×10^{-5}	10.55	13.60	14×10^{-5}	4.62	20×10^{-5}	4.35
		8	2							
		9	1	11×10^{-4}	11.99	17.73	14×10^{-4}	6.25	20×10^{-4}	5.13
		10	2							
		11	1	114×10^{-2}	14.25	19.64	14×10^{-2}	7.56	20×10^{-2}	6.46
		12	2							
	Brazilian split	13	1	100×10^{-5}	3.74	3.53	142×10^{-5}	2.77	200×10^{-5}	2.83
		14	2							
		15	1	55×10^{-4}	4.02	3.94	142×10^{-4}	3.43	200×10^{-4}	3.59
		16	2							
		17	1	55×10^{-2}	4.71	4.92	142×10^{-2}	3.85	200×10^{-2}	4.24
		18	2							
Compressive		19	1	114×10^{-5}	56.27	30.97	142×10^{-5}	36.84	200×10^{-5}	37.24
		20	2							
		21	1	113×10^{-4}	59.77	58.06	142×10^{-4}	39.05	200×10^{-4}	41.38
		22	2							
		23	1	114×10^{-2}	63.43	63.79	142×10^{-2}	42.62	200×10^{-2}	51.94
		24	2							



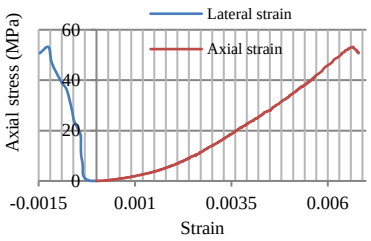
(a)



(b)



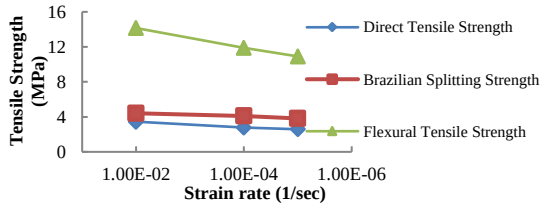
(c)



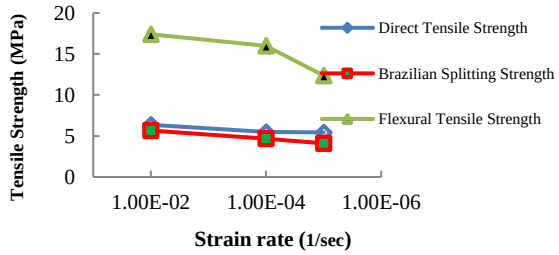
(d)

Fig. 5: stress-strain curve of marble at strain rate 10^{-5} s^{-1} for (a) direct tensile (b) Brazilian splitting (c) Flexural (d) Compression

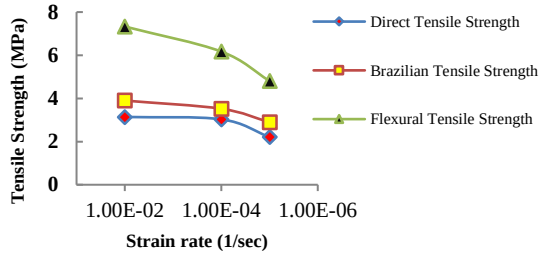
Variation of tensile strength of marble, travertin, mortar and shotcrete specimens with strain rates obtained by the different test methods are shown in figures 6.



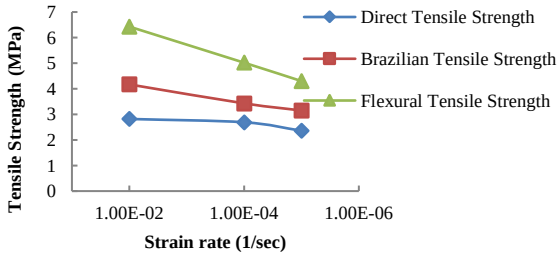
(a)



(b)



(c)



(d)

Fig. 6: Variation of tensile strength with strain rates obtained using different test methods for (a) marble specimens (b) travertine specimens (c) mortar specimens (d) shotcrete specimens

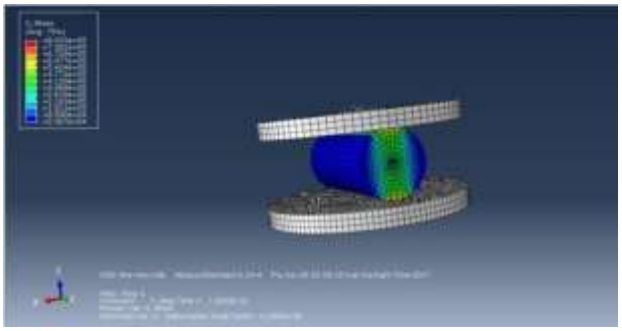
The outcomes demonstrate that the elasticity of the solid and shake tests, acquired by upheld test strategies in this exploration, expanded with expanding strain rate and the adjustments in the rigidity with strain rate were close for all examples tried. Strikingly, unmistakably concrete is an extremely strain rate touchy material. Solid examples indicated expanded elasticity at high strain rate. This expansion is an about straight increment in rigidity with each level of increment in strain rate. The variety of rigidity among various testing techniques saw in this examination concurs with the outcomes announced by different specialists [4]. For both direct pressure and aberrant strain under a similar strain rates, the cracked surfaces of the considerable number of examples turned out to be increasingly smoothed with the expanding strain rate. All types of shake breakage are caused by the expansion of at least one splits [24].

3.2. Numerical Work Result

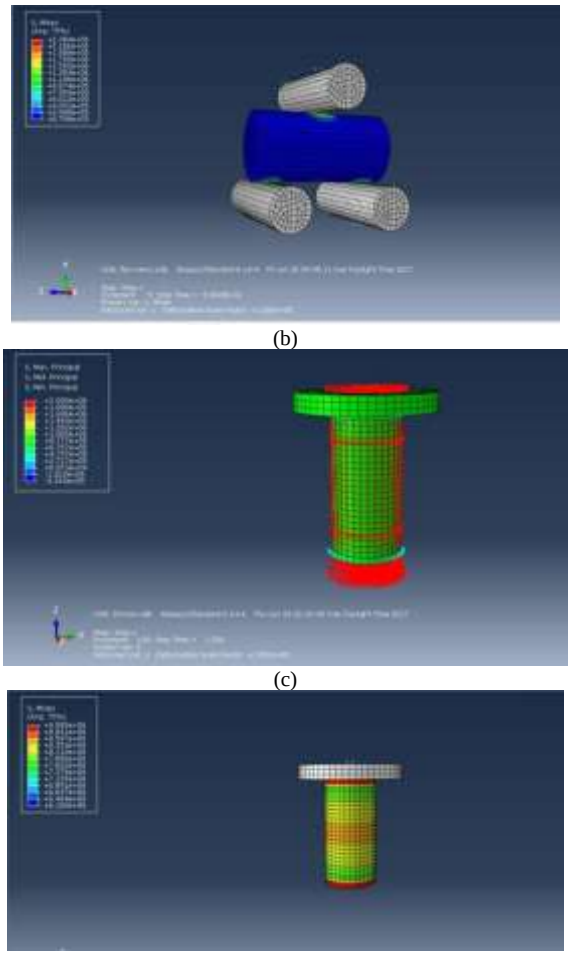
The purpose of numerical modelling work was to validate the experimental results and evaluated and compared with the theoretical data obtained from Abaqus 6.14 [6], [7], [19], [22], [25]. For this reason, a test (Direct tension, Brazilian splitting, and Flexural and Uniaxial compression) model similar to laboratory test in the diameter and thickness was made in Abaqus, as shown in the figure 7, using the compression test data and the elastic and plastic coefficients, to predict the tensile behavior of the materials. For a more even distribution of elements, Cubic 8-shaped mesh (with name C3D8R) was built. A total of three models was according to the census of strain rate (10^{-5}, 10^{-4} and 10^{-2} s^{-1}) for each test of concrete and rocks.

Table 5: Specifications of Materials in Numerical Modelling

Type of Material			Strain rate (s^{-1})	Strain rate (mm/s)	Plastic Coefficient				Elastic Coefficient		Compressive Strength (MPa)
					γ	ε	σ_{bo}/σ_{co}	K_c	E_o (Gpa)	ν	
Concrete		Shotcrete	10^{-5}	0.002	35	0	1.16	0.67	6.5	0.23	37
			10^{-4}	0.02					7.0	0.13	41
			10^{-2}	2.0					8.3	0.11	52
		Mortar	10^{-5}	0.00141					7.0	0.03	36
			10^{-4}	0.0141					7.0	0.05	39
			10^{-2}	1.41					8.0	0.10	42
Rock		Marble	10^{-5}	0.00141					13	0.22	56
			10^{-4}	0.0141					15	0.23	60
			10^{-2}	1.41					18	0.24	63
		Travertin	10^{-5}	0.00141					10	0.16	31
			10^{-4}	0.0141					12	0.14	58
			10^{-2}	1.41					17	0.14	64



(a)



(b) (c) (d)

Fig. 7: The model of an (a)Brazilian (b) flexural (c) direct tension (d) uniaxial compression specimen:3D model

Table 6 and 7 presents a summary of the numerical results for marble, travertine, and mortar and shotcrete samples at different strain rates (10^{-5}, 10^{-4} and 10^{-2}) s^{-1}.

Table 6: Numerical results for rock samples obtained by different methods

Test name		Serial #	Marble		Travertine	
			Strain rate ($mm \times s^{-1}$)	Strength (MPa)	Strain rate ($mm \times s^{-1}$)	Strength (MPa)
Direct tension		1	115×10^{-5}	2.31	115×10^{-5}	5.19
		2	114×10^{-4}	2.58	114×10^{-4}	5.01
		3	115×10^{-2}	3.40	115×10^{-2}	5.79
Indirect tension	Three point	4	110×10^{-5}	9.82	110×10^{-5}	14.5
		5	110×10^{-4}	9.90	110×10^{-4}	16.5
		6	115×10^{-2}	9.98	115×10^{-2}	20.0
	Brazilian split	7	100×10^{-5}	3.44	100×10^{-5}	3.28
		8	55×10^{-4}	3.61	55×10^{-4}	4.40
		9	55×10^{-2}	4.85	55×10^{-2}	5.48
Compressive		10	114×10^{-5}	57.6	115×10^{-5}	24.5
		11	113×10^{-4}	61.1	113×10^{-4}	57.1
		12	114×10^{-2}	62.8	114×10^{-2}	62.4

Table 7: Numerical results for concrete samples obtained by different methods

Test name		Serial #	Mortar		Shotcrete	
			Strain rate ($mm \times s^{-1}$)	Strength (MPa)	Strain rate ($mm \times s^{-1}$)	Strength (MPa)
Direct tension		1	141×10^{-5}	2.03	200×10^{-5}	2.09
		2	143×10^{-4}	2.56	200×10^{-4}	2.39
		3	142×10^{-2}	2.74	200×10^{-2}	2.65
Indirect tension	Three point	4	100×10^{-5}	4.59	200×10^{-5}	3.83
		5	140×10^{-4}	5.61	200×10^{-4}	5.09
		6	142×10^{-2}	7.17	200×10^{-2}	6.02
	Brazilian split	7	100×10^{-5}	2.76	200×10^{-5}	2.05
		8	140×10^{-4}	3.14	200×10^{-4}	2.45
		9	142×10^{-2}	3.66	200×10^{-2}	4.00
Compressive		10	140×10^{-5}	31.6	200×10^{-5}	36.7
		11	140×10^{-4}	32.8	200×10^{-4}	37.8
		12	142×10^{-2}	42.7	200×10^{-2}	50.0

The change of tensile strength of numerical results for samples of the marble, travertin, mortar, and shotcrete with strain rates are shown in figure 8. The change of tensile strength of numerical results for samples of the marble, travertine, mortar, and shotcrete with strain rates are shown in figure 8.

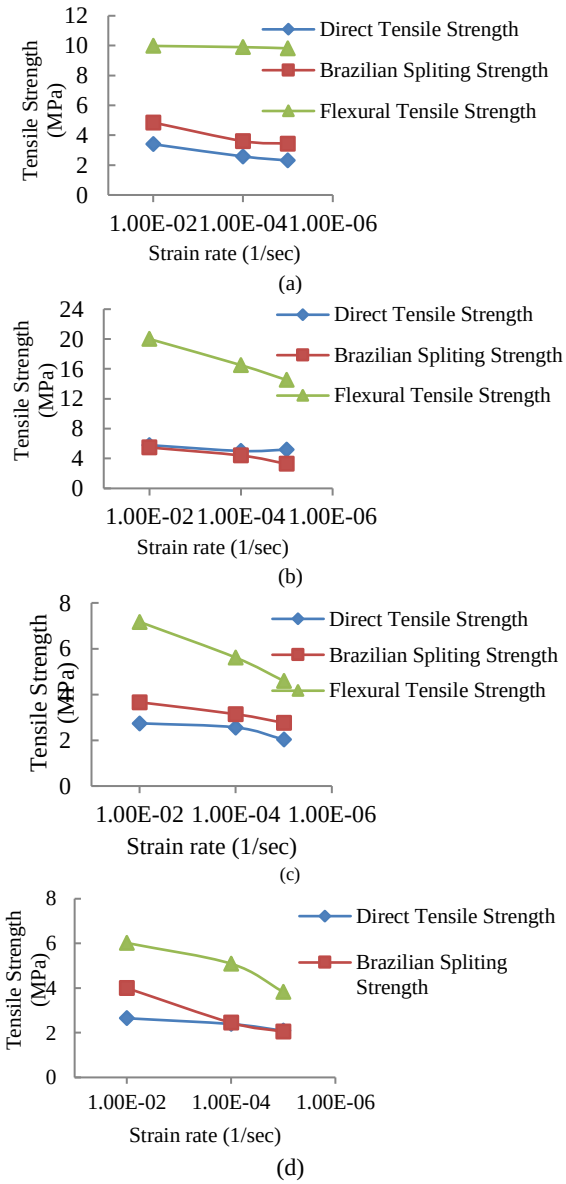


Fig. 8: Change in tensile strength of numerical results with different strain rates for (a) marble specimens (b) travertine specimens (c) mortar specimens (d) shotcrete specimens

Several authors have observed that when strain rates exceed a certain value in the tensile strength rises rapidly with further in-

creases in rate [4], [7], [8], [23], [26], [27], [28]. The maximum tensile strength estimated using Abaqus for all tests and also all tested materials were compared to the laboratory result, as present in Table 8. Numerical results showed reasonably good agreement with experimental results. The estimated about 11%-18% difference for the maximum direct and indirect tensile strength obtained by the numerical and experimental results in this investigation. This is attributed to the simplification used in the numerical modelling.

Table 8: Comparison of experimental and numerical results for all samples

Name Test	Strain rate s^{-1}	Marble			Travertine			Shotcrete		
		Maximum Strength (MPa)		Validity Ratio(%)	Maximum Strength (MPa)		Validity Ratio(%)	Maximum Strength (MPa)		Validity Ratio(%)
		Numerical	Experimental		Numerical	Experimental		Numerical	Experimental	
Direct Tensile – Direct tension	10^{-5}	2.31	2.64	12.5	5.01	6.25	19.8	2.09	2.36	11.4
	10^{-4}	2.58	3.09	16.5	5.19	7.19	27.8	2.39	2.69	11.2
	10^{-2}	3.40	3.30	3.0	5.79	6.97	16.9	2.65	2.82	6.0
Indirect Tensile – Brazilian split	10^{-5}	3.44	3.74	8.0	3.28	3.53	7.00	2.05	2.50	18.0
	10^{-4}	3.61	4.02	10.1	4.40	3.94	11.6	2.45	3.75	34.7
	10^{-2}	4.85	4.71	2.9	5.48	4.92	11.3	4.00	4.31	7.2
Indirect Tensile – Three-point loading	10^{-5}	9.82	10.55	6.9	14.5	13.60	6.60	3.83	4.39	12.8
	10^{-4}	9.90	11.99	17.4	16.5	17.73	6.90	5.09	5.23	2.7
	10^{-2}	9.98	14.25	29.9	20.0	19.64	1.80	6.02	6.49	7.2
Uniaxial Compression	10^{-5}	57.6	56.27	2.3	24.5	30.97	20.8	36.7	37.05	0.9
	10^{-4}	61.1	59.77	2.2	57.1	58.06	1.60	37.8	40.74	7.2
	10^{-2}	62.8	63.43	1.0	62.4	63.79	2.10	50.0	52.27	4.3

Name Test	Strain rate s^{-1}	Mortar		
		Maximum Strength (MPa)		Validity Ratio(%)
		Numerical	Experimental	
Direct Tensile – Direct tension	10^{-5}	2.03	2.21	8.1
	10^{-4}	2.56	3.03	15.5
	10^{-2}	2.74	3.14	12.7
Indirect Tensile – Brazilian split	10^{-5}	2.76	2.90	4.8
	10^{-4}	3.14	3.52	10.8
	10^{-2}	3.66	3.90	6.2
Indirect Tensile – Three-point loading	10^{-5}	4.59	4.81	4.6
	10^{-4}	5.81	6.17	5.8
	10^{-2}	7.17	7.33	2.2
Uniaxial Compression	10^{-5}	31.6	36.27	12.9
	10^{-4}	32.8	39.07	16.0
	10^{-2}	42.7	42.90	0.5

3.3. The direct tension test

All examples of cement and shakes demonstrate sudden crack as pinnacle quality are come to and with a greater clamor when strain rates of 10−4 and 10-2 s-1 were connected. The event of the best elastic qualities was in near the focal point of the considerable number of examples, as appeared in Figure 2 (a). It is discovered that the rigidity acquired from the immediate pressure test plainly increments with expanding strain rate. At the point when the strain rate increments from 10-5, 10-4 and 10-2 s-1, the elasticity roughly expanded by around 17, 15, 23 and 11% for marble, travertine, mortar, and shotcrete, separately. This pattern is an about straight increment in elasticity with each request of size increment in strain rates. Table 9 demonstrates the connection between direct rigidity and strain rate for marble, travertine, mortar, and shotcrete examples.On the basis of the results showed here, the direct tensile strength of concrete was less sensitive to an increase in the strain rate than the rest of the tests. Several explanations can be suggested to account for these trends. One explanation may be based on fracture mechanics concepts or combining the subcritical crack growth and fracture process zone according to [7] or this has been attributed to the effects of inertial confinement [29].

3.4. The Brazilian split test

As appeared in Figure 2 (b), the example has a normal disappointment and creates breakage on the distance across of the stone toward the path parallel to the outer power. The two segments delivered in the wake of part has an underlying speed to the contrary side and flies out with higher sound. The higher the strain rate, the more prominent the parts' underlying speed and the more prominent the sound. In the all tests completed, some case had been found. The vast majority of the tests could be delegated "right tests". It is discovered that the rigidity got from the Brazilian split test unmistakably increments with expanding strain rate. At the point when the strain rate increments from 10-5, 10-4, 10-2 s-1, the elasticity expanded by around 7, 11, 23 and 26% for marble, travertine, mortar, and shotcrete, separately.

The rigidity of all examples got from the immediate pressure test was marginally lower than that gotten from the Brazil test. For instance, for the strain rate of 10-5 s-1, the elasticity from the immediate pressure test is 2.64, 3.53, 2.42 and 2.41 MPa for marble, travertine, mortar, and shotcrete, individually. While, it is 3.74, 6.25, 2.77 and 2.83 MPa from the Brazil test, individually. Similar to the case for, the rest strain rates. As a rule, the elasticity acquired by the immediate pressure test at various strain rates con-

curs well with that got from the Brazil test as indicated by [2]. Table 9 demonstrates the connection between part rigidity and strain rate for marble, travertine, mortar, and shotcrete examples.

3.5. Three-point flexural stacking test

Figure 2 (c) demonstrates the flexural disappointment method of Mortar. The disappointment area of all examples tried was at the mid-separate and no impact of the strain rate was noted. Along these lines, for all examples tried exposed to flexure, strain rates did not impact the disappointment design. It ought to be noted at quicker strain rate causes all the more quickly shake disappointment, higher speed of the harmed parts to fly out and further clamor. Equivalent to the two tests referenced over, the expansion the strain rate prompts the more prominent flexural rigidity. Table 9 demonstrates the connection between flexural quality and strain rate for marble, travertine, mortar, and shotcrete examples.

Table 9: shows the relation between tensile strength and strain rate for marble, travertine, mortar, and shotcrete specimens.

Types of material	Direct tension test $\sigma_t =$	Brazilian split test $\sigma_{BST} =$	Three-point flexural loading test $\sigma_t =$
Marble	$3.75 + 0.20 \log \dot{\varepsilon}$	$5.35 + 0.32 \log \dot{\varepsilon}$	$16.73 + 1.21 \log \dot{\varepsilon}$
Travertine	$7.82 + 0.30 \log \dot{\varepsilon}$	$5.84 + 0.46 \log \dot{\varepsilon}$	$23.81 + 1.86 \log \dot{\varepsilon}$
Mortar	$3.69 + 0.22 \log \dot{\varepsilon}$	$4.59 + 0.33 \log \dot{\varepsilon}$	$9.56 + 0.93 \log \dot{\varepsilon}$
Shotcrete	$3.16 + 0.14 \log \dot{\varepsilon}$	$5.20 + 0.44 \log \dot{\varepsilon}$	$7.87 + 0.69 \log \dot{\varepsilon}$

Where σ_t, σ_{BST} and $\dot{\varepsilon}$ are direct tensile strength (MPa) or indirect tensile strength by the Three-point loading test (MPa), indirect tensile strength by the Brazilian test (MPa) and strain rate (s^{-1}), respectively.

4. Conclusion

The accompanying ends are clarified from the direct tractable results(by coordinate strain test) and backhanded elastic outcomes (by Brazilian split and three-point flexural stacking test) and talk displayed in this paper. All examples were stacked at various strain rates with various gatherings and each gathering comprised of two examples for marble, travertine, mortar, and shotcrete for all tests.

1- The broke surfaces of the considerable number of examples in all tests turned out to be increasingly straightened with the expanding strain rate.

2- All examples of cement and shakes demonstrate unexpected crack as pinnacle quality are come to in all tests with greater commotion for strain rates of 10-4 and 10-2 s-1.

3- The aberrant elastic qualities of cement were more touchy to an expansion in the strain rate than rest of the examples tried. A few clarifications can be proposed to represent these patterns. One clarification might be founded on break mechanics ideas or joining the subcritical split development and crack process zone.

4- Strain rates importantly affect expanded the immediate and roundabout elasticity of cement and shake. The immediate and backhanded elasticity would increment with the strain rate expanding.

5- The trial results were contrasted and the consequences of numerical demonstrating utilizing Abaqus 6.14 for all tests and furthermore all tried materials. Where the inexact 11%-18% distinction for the greatest immediate and aberrant elastic qualities acquired by numerical and test results. This is ascribed to the rearrangements utilized in the numerical demonstrating. The examination demonstrated that the exploratory outcomes for the most part are in great concurrence with the aftereffects of Abaqus investigation.

6- Compared with the direct elasticity of travertin under the strain rate of 10-5 s-1, the direct rigidity under the strain rates of 10-4 and 10-2 s-1 expanded 15.0%, and 11.0%, individually. While for marble expanded direct rigidity under the strain rates 10-4 and 10-2 s-1 of 17.0%, and 25.0%, separately. With respect to the solid, expanded the direct elasticity of mortar under the strain rates 10-4 and 10-2 s-1 of 23.0%, and 30.0%, individually. While for shotcrete expanded direct elasticity under the strain rates 10-4 and 10-2 s-1 of 11.0%, and 18.0%, separately.

7- Compared with the roundabout rigidity of travertin under the strain rate of 10-5 s-1, where the Brazilian elasticity under the strain rates of 10-4 and 10-2 s-1 expanded 11.6%, and 39.3%, individually. While for marble expanded Brazilian elasticity under the strain rates 10-4 and 10-2 s-1 of 7.5%, and 25.9%, individually. Concerning the solid, expanded Brazilian rigidity of mortar under the strain rates 10-4 and 10-2 s-1 of 23.8%, and 38.9%, separately. While for shotcrete expanded Brazilian elasticity under the strain rates 10-4 and 10-2 s-1 of 26.8%, and 49.8%, individually.

8- Compared with the aberrant elasticity of travertin shake under the strain rate of 10-5 s-1, where the flexural rigidity under the strain rates of 10-4 and 10-2 s-1 expanded 30.3%, and 44.4%, separately. While for marble rocks expanded flexural elasticity under the strain rates 10-4 and 10-2 s-1 of 13.6%, and 35.0%, individually. With respect to the solid, expanded the flexural rigidity of mortar under the strain rates 10-4 and 10-2 s-1 of 35.3%, and 63.6%, separately. While for shotcrete expanded flexural elasticity under the strain rates 10-4 and 10-2 s-1 of 17.9%, and 48.5%, separately.

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