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EFFECT OF ACCIDENTAL MATERIALS ON THE PROPERTIES OF CONCRETE

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General

Preface: The main object of this report is to see the effect of various substances on concrete. One of the most important requirements of concrete is that it should be durable under certain conditions of exposure. In this thesis the nature and consequences of the interaction of various substances are: -
Acids, Sulphates, Chlorides, Carbonates, Salts and alkalis, Sulfur and Phosphates, Petroleum oils, Vegetable oils, miscellaneous substances i.e. Juices, Sugar solution, Sewage, Pepsi etc.

Chemical effect on concrete: Dry concrete is generally immune to attack by dry chemicals. Higher is the temperature, higher is the rate of attack and similar behavior for pressure. Concrete in soil carrying waters containing aggressive chemicals is usually not attacked as rapidly as concrete of the same quality exposed to moving surface waters of same chemicals composition because soil reduce the rate of renewal of these chemicals at the concrete surface. In practice several degradation mechanisms can act simultaneously with possible synergistic effects.

Experimental Study:
The constituent materials are cement (OPC), fine aggregate (dry lawrencepur sand), coarse aggregate (saturated Margalla crush) retained on #3(3/8") B.S.S and passing #6 (3/4") B.S.S ,retained, (3/16") B.S.S & passing #3 (3/8") B.S.S.Tap ordinary water

collected from water supply (underground water) at room temperature shall be used.

Properties of constituent

Specific Gravity S_G

Cement: 3.14

Lawrencepur Sand: 2.70

Margala Crush: 2.69

Bulk density

Cement: Nil

Lawrencepur Sand: 96.48PCF

Margala Crush: 93.13 PCF

1:2:4 by weight mix proportion of concrete mix

W/C = 0.55

Casting Procedure adopted : Liquid solution were taken by weight of cement but water required for w/c is 0.55 was sum of liquid and water , but in case of solid substance required amount of water according to w/c ratio was used .Curing were done by immersion in water for 14/15 days. At 28 days fc'(concrete crushing compressive strength) of plain concrete cube 4" x 4" x 4" is 20 MPa or 3000 PSI (avg. of 2 cubes strength). However 7 days,14 days, 2 months, 3 months and 4 months age compressive strength is also determined in lab on 300 ton testing machine & steel models of 4" x 4" x 4". Two types of methods adopted are when mixed with concrete ingredients as replacement of water and 2nd by immersion in accidental material solution. Both results were tabulated and scientific discussion were carried out.

EFFECT OF ACIDS:

Scientific Discussion Concrete is chemically basic, having a pH of 13. An acidity represented by a PH 5.5 – 6 may be considered the practical limit of tolerance of high-quality concrete. It should be remembered that no OPC is acid resistant. In practice an attack occurs at a value of pH below than 6.5. Concrete is also attacked by water containing freeCO_2.Flowing pure water also dissolves Ca $(OH)_2$thus causing surface erosion. Water with $CO_2$is aggressive with pH as 4.4. This type of attack may be important in conduits in mountains regions, for durability and thus increase the roughness of pipe. The behavior of concrete exposed to acidic soil; water has been reviewed by Ellington German classification is given in table below as:

Degree of aggressiveness	Aggressive Action by		
	Water		Soil
	pH	Aggressive CO_2 (ppm)	Exchangeable acids (0.1 N) ml/ 100 g of soils
Slight	6.5 – 5.5	15 – 30	20
Severe	5.5 – 4.5	30 – 60	-
Very Severe	< 4.5	>60	-

H2S gaH_2S gas dissolved in water form a weak acid with mild corrosive action on concrete. Principally, in sewers carrying organic waste, H_2S can be oxidized by bacterial action to H_2SO_4 which can attack concrete. The attack occurs above the level of flow of sewage. The cement is gradually dissolved & progressive deterioration of concrete take place. Portland blast furnace cement and plasticizers i.e. pozzolaneous with Portland cement are used in acidic solutions. Good protection of the concrete from acid attack is obtained by subjecting the concrete in a vacuum to the action of silicon tetrafluoride gas. The treatment applied to precast concrete known as ocrat – concrete.

SULFURIC ACID H_2SO_4

When mixed in concrete: Sulfuric acid is available in liquid form, having odors & bad smell as well as very dangerous to the skin, if applied

pH	Solution of H_2SO_4 depth of deterioration of concrete cm, for theoretical life of structure, Yrs		
	25	**50**	**100**
2	5.4	7.6	10.8

3	1.7	2.4	3.4
4	0.5	0.7	1.1
4.5	0.3	0.4	0.6
5	0.2	0.3	0.4

Ref:Durability of reinforced concrete in aggressive media by S.N Alekseen of OPC at w/c = 0.6

10% of H_2SO_4 acid was tried by weight of cement but mix appeared like a dried material and destroyed the cement binding power. Afterword 5% of H_2SO_4 acid by weight of cement was used. The increased strength is much lower than the corresponding PCC cube strength. Highly disappearance was observed at the surface. The compressive strength at 28 days fc' is 5.497 MPa or 785.30 PSI.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
7	3.43	3.43	3.43
30	4.91	6.87	5.89
60	4.91	7.36	6.14
90	16.19	15.70	15.95
120	16.68	15.70	16.19

On Concrete Surface/ by immersion in diluted acid : Generally there are certain chemical factories in which sulfuric acid is used. When this H_2SO_4 leaked through the vessels, in which it was stored and spread over the concrete surface and thereby damages the structure.5% solution of H_2SO_4 was prepared and a pH of 4.0 is observed. Sulfuric acid attacks the cement and not with the aggregate, so reaction is with cement not with the aggregate. The compressive strength fc' at 28 days is 32.35 MPa or 4622 PSI.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
21	32.37	30.41	31.39
42	38.01	38.26	38.14
70	32.37	33.45	32.86
90	36.30	38.26	37.28
120	39.24	44.15	41.70

NITRIC ACID

When mixed in Concrete: Nitric acid is available in liquid form, having odor bad smell as well as very dangerous to the skin if applied. 2 cubes each for 7,30,60,90,120 days were tested by using 5% of HNO_3 by weight of cement. At 28 days fc' (concrete crushing compressive strength in MPa) is 16.04 MPa or 2292 PSI.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
7	14.72	14.22	14.47
30	15.70	16.68	16.19
60	31.39	32.86	32.13
90	37.28	37.77	37.53
120	38.26	37.28	37.77

On concrete surface/ immersed in diluted acid: - Generally there are certain chemical factories in which nitric acid is used. When this nitric acid leaks through the vessel, in which it was stored& spread over the crack surface and thereby damages the structure. The chemical lining is done on and surrounding the surface where these chemicals are to be stored. When concrete specimen is immersed in nitric acid solution of 5% by weight of cement and pH value of 3 is observed with colored pH paper which shows highly acidic solution. The concrete compressive strength is 36.713 MPa or 5245 PSI.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
21	35.81	36.30	36.06
42	37.77	38.26	38.02
70	40.22	40.22	40.22
90	40.22	40.22	40.22
120	41.20	42.18	41.69

pH	**Solution of HNO_3**		
	Dept of water deterioration of concrete, cm, for theoretical service life of structures, years.		
	25	**50**	**100**
2	2.8	8.2	11.6
3	1.8	2.5	3.7
4	0.6	0.8	1.2
4.5	0.3	0.4	0.6
5	0.2	0.3	0.4

Ref:Durability of Reinforced concrete in Aggressive media by S.N.Alekseenof OPC at w/c = 0.6

HYDROCHLORIC ACID:

When mixed in Concrete: HCl is available in liquid form. Cubes were prepared using 5% of HCl by the weight of cement. Slightly less workability of concrete was observed. Little effect is seen on the surface by usual appearance. The compressive strength at 28 days fc' is 23.36 MPa or 3337 PSI.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
7	16.68	15.70	16.19
30	28.45	19.62	24.04
60	32.37	32.86	32.62
90	35.32	34.34	34.83
120	36.30	35.06	36.06

Effect Of HCl acid on Concrete Surface: Generally there are certain chemical factories in which HCl is used when this HCl is leaked through vessels, in which it was stored and spread over the concrete surface and thereby damages the structure. Chemical lining to this surrounding surface is applied on the concrete surface where these chemicals is to be stored. However, the purpose is to see the effects of HCl on the strength of concrete when concrete specimen is immersed in acidic solution. 5% HCl was prepared and immersed in water for 14 days of curing. A pH of 4, a highly acidic solution was obtained. The compressive strength at 28 days, fc' of 33.193 MPa or 4742PSI.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
21	29.43	31.88	30.66
42	37.28	39.24	38.26
70	39.73	40.22	39.98
90	40.22	39.24	39.73
120	41.20	41.20	41.20

pH	Solution of HCl		
	Depth of deterioration of concrete, cm, for theoretical service of structure, Years.		
	25	50	100
2	2.8	8.2	11.6
3	1.8	2.5	3.7
4	0.6	0.8	1.2
4.5	0.3	0.4	0.6
5	0.2	0.3	0.4

Durability of Reinforced concrete in Aggressive media by S.N Alekseen of OPC at w/c = 0.60

EFFECT OF SULPHATES:

Scientific discussion : Solid salts do not attack concrete, but when present in solution they can react with hardened cement paste. Some clay contains for instance alkali, magnesium, $CaSO_4$and ground water. Gypsum and Calcium sulphone-aluminate have reaction with sulphates leads to expansion and disruption of concrete. Attack of $MgSO_4$ is more severe than by other sulphates. Concrete attacked by sulphates have a whitish appearance. Sulphate resisting cement is suggested for sulphate attack. The use of pozzalanas instead of cement resists sulphate attack.

Sea water contains sulphates ,concrete b/w tide marks subjected to drying and wetting is severely attacked ,while immersed in water is least attacked. In RCC the concrete cover is 2 to 3 in. A w/c ratio of not more than 0.40 is recommended.

Classification of sulphate attack vide ACI 318 :When sulphate contents are 0.1 % in soil or under 150 ppm(mg/litre) in water, any cement type and w/c ratio may be used. This is negligible attack. When 0.1 %-0.2% sulphate content or 150-1500 ppm in water, ASTM type-II Portland cement or Portland pozzolanic or Portland slag cement with less than as 0.5 w/c ,for normal weight concrete shall be used. This is moderate attack. When the sulphate contents are 0.2%-2% in soil, or 1500-10000 ppm in water, ASTM type V Portland cement with less than or equal to 0.45 w/c shall be used. This is severe attack. When the sulphate contents is greater than 2% in soil or over 10,000 ppm in water ASTM type V cement plus a Pozzolanic admixtures with less than 0.45 % shall be used.

Concentration of asphalt expressed as SO3				Type of cement	Min cement contact in kg/m3 for nominal max size of aggregates			Max free w/c ratio
In soil								
Class	Total SO3 present	SO3 in 2:1 (water:Soil)extract) gm/ltr	In ground water (ppm)		40 mm	20mm	10 mm	
1	< 0.2	0	< 300	OPC or blast	240	280	330	

				furnace cement				
2	0.2-0.5	0	300-1200	OPC or blast furnace cement	290	330	380	0.55
				Sulphate resisting Portland	240	280	330	0.55
				Supersulphated	270	310	360	0.5
3	0.5-1.0	1.9-3.1	1200-2500	Sulphate resisting Portland or supersulphated	290	330	380	0.5
4	1.0-2.0	3.1-5.6	2500-5000	Sulphate resisting Portland or supersulphated	330	370	420	0.45
5	Over 2	Over 5.6	Over 5000	As for class 4, but an addition of adequate protective coatings of inert material such as asphalt or bituminous emulsions reinforced with fiber glass membranes.				

EFFECT OF $MgSO_4$ (MAGNESIUM SULPHATE):

Scientific Discussion :It is also used in tanning, but beyond a concentration of about 0.5% about of Mg SO_4 or 1% of Na_2SO_4 the rate of increase in the intensity of the attack becomes smaller. A saturated solution of $MgSO_4$ leads to serious deterioration of concrete. The concentration of sulphates as a number of parts by weight of SO_3 /million PPM is 1000 ppm is considered moderately severe and 2000 ppm are very severe. In order to estimate the danger of the sulphate attack the movement of ground water has to be known. Sulphate bearing water rate of attack is highest. Likewise alternate saturation and drying lead to rapid deterioration. When concrete attacked by sulphate at edges & corners and progressive cracking to friable or even soft state. In practice sulphate resisting cement C_3A and pozzolaneous is better to use where sulphate attack is suspected .However , British code of practice CP 110:1972 and BS 5328:1976 allows not to use fly ash with sulphate resisting cement. The resistance of concrete to sulphate attack depends also on its impermeability.

When mixed in concrete :Hydrated magnesium sulphate($MgSO_4.7H_2O$) is also called 'Epsom salt' .It is colorless crystalline solid. It is soluble in the water and get moisture in open atmosphere.5% $MgSO_4$ was used in the concrete mix. Concrete became very dry and less workable when it was mixed in the concrete. The compressive strength at 28 days fc' was 25.39 MPa or 3627 PSI (avg. of two cubes).

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
7	26.98	26.49	26.74
30	26.49	24.03	25.26
60	27.96	28.45	28.21
90	29.43	30.41	29.92
120	31.39	31.39	31.39

On the surface of concrete :$MgSO_4$ is largely used in ceramics ,cement ,soap and paper industry. Plain concrete cubes were immersed in solution of 5% Mg SO_4 , pH value of 9, alkaline. The compressive strength at 28 days fc' is 35.07 MPa or 5010 PSI.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
21	33.45	32.86	33.11
42	38.75	39.24	39.00
70	41.20	41.20	41.20
90	39.24	40.22	39.73
120	38.26	41.20	39.73

SODIUM SULPHATE:

Effect of Na_2SO_4 when mixed in concrete__:-5% sodium sulphate was used in the concrete mix. The workability of the concrete mix was increased. The compressive strength at 28 days fc' is 24.22 MPa or 3460 PSI.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
7	19.87	22.07	20.97
30	23.54	25.51	24.53
60	33.35	34.34	33.85
90	36.30	36.54	36.42
120	38.75	39.24	39.00

Effect of Na_2SO_4 when applied on concrete surface: -5% Na_2SO_4 shows pH value of 11,alkaline in nature .The compressive strength at 28 days fc' is 35.48 MPa or 5069 PSI.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
21	31.88	34.34	33.11
42	37.28	43.16	40.22
70	27.47	28.45	27.96
90	29.43	31.39	30.41
120	31.39	35.32	33.36

CALCIUM SULPHATE:

Effect of $CaSO_4$ when mixed in concrete :

Calcium sulphate is available in anhydrous as well as in hydrous form. Dehydrated form is called Gypsum. It is sparingly soluble in water. It was used in solid form while preparing the concrete mix.5% by weight of cement of calcium sulphate on 7,30,60,90 and 120 days on avg of 2 cubes (British standard specification). The compressive strength at 28 days fc' is 28.91 MPa or 4130 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
7	20.60	21.09	20.85
30	29.43	29.92	29.68
60	41.20	43.16	42.18
90	44.15	44.65	44.40
120	45.13	45.13	45.13

On surface of concrete:$CaSO_4$ is used in making plaster of Paris ,wall-board, fertilizers and glazing papers. Concrete structures in these industries are effected by $CaSO_4$.10 numbers cubes of concrete are immersed for 15 days in solution of 5% $CaSO_4$.The compressive strength of 28 days , fc' is 34.50MPa or 4929 PSI.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
21	32.37	33.35	32.86
42	37.28	38.26	37.77
70	39.24	40.22	39.73
90	39.24	38.26	38.75
120	41.20	40.22	40.71

COPPER SULPHATE:

Effect of $CuSO_4$ when mixed in concrete: Copper sulphate($CuSO_4.5H_2O$) is also called Nila thotha. It is a blue crystalline efflorescence solid. It is highly soluble in the water. It was used in solution form in the concrete while mixing. The compressive strength of avg of 2 numbers cubes tested in compressive testing machine shows at 28 days ,fc' is 27.107 MPa or 3873 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
7	17.66	18.64	18.15
30	27.47	28.45	27.96
60	37.28	37.77	37.53
90	39.24	41.20	40.22
120	42.18	40.71	41.45

Effect of $CuSO_4$ when applied on concrete surface: $CuSO_4$ is used in copper refining ,electroplating, Calcio dying and printing industries.10 numbers cubes prepared by 21,42,70,90,120 days after 14/15 days curing in 5% solution of water and avg of 2 nos cubes compressive strength, fc' at 28 days is 35.07 MPa or 5010 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
21	31.88	34.34	33.11
42	38.75	39.24	39.00
70	40.71	41.20	40.96
90	39.24	38.26	38.75
120	37.28	36.30	36.79

EFFECT OF ALKALIES:

Scientific Discussion: Alkalis may be defined as chemical compound which yield hydroxyl OH^{-1} ions in water solution .They have pH value more than 7.Common examples are sodium hydroxide, Calcium hydroxide and ammonium hydroxide .Concrete is unaffected by continuous exposure to 10 % solution of sodium or potassium hydroxides. Calcium, ammonium, barium and strontium hydroxides are harmless to concrete. Concentrated basic solution (having above 20%) corrosion may occur to concrete. Pozzolanic cements should not be used for concrete subjected to strong basic solutions. Alkali aggregate reaction is b/w certain highly silicious constituents of aggregates and cement having high alkali contents results in strength loss, excessive expansion, cracking and disintegration's expansion may close the expansion joints dislocate structural members, cause machinery to be disclosed. The alkali silica reaction (ASR) occurs in a concrete pavement and hence cracking in within 5-10 years. We are investigating several geochemical and mineralogical issues related to ASR.ASR is often detected using a geochemical labeling techniques. AAR(Alkali Aggregate reaction) in which sodium and potassium ions in solution react with certain types of aggregates in concrete .The reaction forms a hydroscopic alkali-silica gel which enable water and swell. The swelling forces generated may be sufficient to disrupt aggregate and the surrounding concrete, causing expansion, cracking, and associated deterioration.

Enrichment concentration and recycling of alkalies in concrete It has been suggested that moisture mobility through concrete can cause alkali metal salts to migrate and create temporary or permanent concentrations of these salts in some regions of the concrete.

SODIUM HYDROXIDE:

Effect of NaOH when mixed in concrete :NaOH is available in white solid form, it is extremely strong base(alkali) and it tends to dissolve the skin, if applied. Its common name is caustic soda and chemical formula is NaOH.

$Na_2CO_3 + Ca(OH)_2$ ------------------ $2\ NaOH + CaCO_3$

$NaOH + H_2O$ --------------------------- $Na^+_{(aq)} + OH^-_{(aq)}$ - 10,000 Calories

10 cubes were cast after mixing 10 % of NaOH by weight of cement. The compressive strength, fc' at 28 days is 14.76 MPa or 2109 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
7	9.81	10.30	10.06
30	14.72	15.70	15.21
60	18.64	18.15	18.40
90	21.58	23.54	22.56
120	23.54	24.03	23.79

On the surface of concrete :It is widely used in the manufacturing of soap, silk finish of mercerized cotton, rubber reclaiming ,paper making ,rayon textile production. It is immersed in NaOH solution the concrete cubes.10% of NaOH shows pH is 14 ,highly basic solution. In addition to decrease in strength, high surface efflorescence was also observed. The compressive strength at 28 days on avg. of two cubes tested was 37.93 MPa or 5419 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
21	36.30	38.26	37.28
42	39.24	39.24	39.24
70	42.18	41.20	41.69
90	37.77	36.30	37.04
120	37.28	38.26	37.77

CALCIUM HYDROXIDE:

Scientific Study: The strongly alkaline nature of $Ca(OH)_2$with pH of 13 prevents the corrosion of the steel reinforcement by the formation of a thin protective film of iron oxide on the metal surface known as ' passivity'. If concrete is permeable then carbonation reaction reaches the concrete with steel or soluble chlorides can penetrate up to reinforcement ,and water and oxygen are present ,then corrosion of reinforcement will take place. The passive iron oxide layer is destroyed when pH falls below 11 and carbonation lowers to 9pH.The formation of rust results in an increase in volume with original steel so swelling pressure will cause cracking and spalling of the concrete. It has been suggested that the optimum relative humidity for corrosion is 70%-80%.Corrosion of steel occurs because of electrochemical action which is met when two different metals are in electrical contact in the presence of moisture and oxygen.

When mixed with in concrete: $Ca(OH)_2$ is available in liquid form and is a base known as lime water. We casted 10 cubes after mixing 10 % of $Ca(OH)_2$ by weight of cement. The deterioration effect was observed when mixed with/in concrete. The compressive strength fc' at 28 days is 23.90 MPa or 3415 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
7	16.68	12.75	14.72
30	24.53	25.02	24.78
60	26.00	25.51	25.76
90	27.47	28.45	27.96
120	30.41	29.43	29.92

On surface of concrete :Chemical lining is carried out where it generally in contact with concrete. However ,the purpose is to see the effect of $Ca(OH)_2$ on the strength of concrete when concrete specimen is immersed in its solution. Solution of 10% $Ca(OH)_2$ shows a pH of 10 ,basic. It was observed that specimen immersed in $Ca(OH)_2$ have very small change in strength .Hence it has less effect as compared to NaOH and NH_4OH.In addition to decrease in strength high surface efflorescence was also observed. The crushing compressive strength fc' at 28 days is 37.94 Mpa or 5420 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
21	35.32	33.35	34.34
42	45.13	45.13	45.13
70	44.15	44.64	44.40
90	45.13	44.15	44.64
120	46.11	45.13	45.62

AMMONIUM HYDROXIDE /AMMONIA SOLN:

When mixed in concrete :-NH_4OH is available in liquid form basically it is a solution of ammonia ,it is strong base and it has very pungent smell.10 cubes were casted after mixing 10 % NH_4OH by weight of cement.NH_4OH results shows has disintegrative effect when mixed in concrete. The compressive strength is 28.59 MPa or 4085 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
7	16.19	18.15	17.72
30	28.45	30.90	29.68
60	35.32	32.37	33.85
90	39.24	40.22	39.73
120	40.22	40.22	40.22

On surface of concrete: It is widely used in the manufacturing of nitric acid, rayon textile production and manufacturing of fertilizers .10% of NH_4OH was prepared, pH of 14 ,basic solution. There is decrease in strength ,high surface efflorescence was also observed. The fc' is 35.15 MPa or 5022 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
21	35.07	33.35	34.21
42	36.79	37.28	37.04
70	40.71	41.20	40.96
90	41.20	39.24	40.22
120	42.18	42.18	42.18

EFFECT OF CARBONATES:

Generic Scientific Study_:Sodium carbonate solution have little or no chemical action on dense matured OPC. Ammonium bicarbonates solution seems to have some actions on concrete .Carbonate aggregates used in concrete are generally provide a strong bond with the cement paste. Certain type of carbonate rocks used as aggregate produce expansion in concrete in the form of pattern or map cracking. Carbonation results in a soft dusty surface to normal concrete. Carbonation is defined as the chemical combining of CO2 with the hydration products of OPC. Carbonation can affect concrete to various degree from a light dust on the surface to a deep of ¼" or more.

SODIUM CARBONATE:

When mixed with concrete :Sodium carbonate is a transparent ,crystalline solid. It is also called washing soda. Anhydrous sodium carbonate is called soda ash. It is highly soluble in water and its solubility is 21.4 gram at 25 ^{0}C.Therefore it was used in solution form while preparing the concrete mix.5% by weight of cement was used. On testing after 7,30,60,90 and 120 days the compressive strength was reduced by 21%,46%,45%,45% and 44% respectively as compared with OPC. The fc' is 21.49 MPa or 3071 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
7	21.58	19.62	20.60
30	22.56	20.60	21.58
60	21.83	22.56	22.20
90	25.75	26.98	26.37
120	27.47	27.47	27.47

When applied on the concrete surface :Na_2CO_3 is largely used in manufacturing of glass, enamels ,soap ,paper and for water softening .10 cubes were Na_2CO_3 having pH value 11.On testing at 42 days strength increased by 23% and after 70 ,90,120 days the strength was reduced to 7%,19%,16% w.r.t plain cubes. The fc' is 36.22 MPa or 5174 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
21	31.39	32.37	31.88
42	44.64	45.13	44.89
70	38.26	37.28	37.77

90	39.24	39.73	39.49
120	41.69	40.22	40.96

CALCIUM CARBONATE:

7.3.1 <u>When mixed in concrete</u> :-$CaCO_3$ is a white crystalline solid. It is slightly soluble in water. It was used in solid form while preparing the concrete mix as it is soluble in water.5% by weight of cement was used.10 nos of cubes were casted and tested. The test results showed that the compressive strength is much less than plain cube strength. The fc' is 21.78 MPa or 3112 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
7	20.00	19.00	19.50
30	23.00	21.00	22.00
60	22.00	23.00	22.50
90	26.00	27.00	26.50
120	28.00	28.00	28.00

On concrete surface:$CaCO_3$ is widely used in medicine.10 cubes were prepared and tested after 14 days curing when immersed in 5% solution of $CaCO_3$.The pH of 8 ,slightly alkaline solution .The fc' is 32.67 MPa or 4667 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
21	28.00	29.00	28.50
42	38.00	44.00	41.00
70	39.00	37.00	38.00
90	40.00	39.73	39.87
120	42.00	40.22	41.11

Magnesium Carbonate:

When mixed in concrete :It is white crystalline solid. It is slightly soluble in water .Since it is soluble in water therefore it was used in solidform.5% by weight of cement was used. The fc' is 20.83 MPa or 2975 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
7	18.00	20.00	19.00
30	22.00	20.00	21.00
60	22.00	23.00	22.50
90	26.00	27.00	26.50
120	28.00	28.00	28.00

On surface of concrete :$MgSO_4$ is widely used in medicines.10 cubes were prepared and immersed for 14 days curing in 5% Mg_2CO_3 solution of concrete cubes. The pH value obtained was 8 alkaline solution .The fc' is 32.33 N/mm^2 or 4619 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
21	27.00	30.00	28.50
42	37.00	43.00	40.00
70	39.00	37.00	38.00
90	39.00	39.73	39.37
120	42.00	41.00	41.50

Sodium Bicarbonate $NaHCO_3$:

When mixed in concrete :It is white crystalline solid. It is slightly soluble in water and its solubility is 8.2 g. Solution of NaHCO3 is alkaline and hydrolyzes in water .Since it is soluble in water therefore it was used in solidform.5% by weight of cement was used. The fc' is 23.95 MPa or 3422 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
7	18.15	17.66	17.91
30	24.53	24.53	24.53
60	32.86	33.35	33.11
90	32.37	31.64	32.01
120	35.32	31.88	33.60

On surface of concrete :$NaHCO_3$ is widely used in medicines.10 cubes were prepared and immersed for 14 days curing in 5% Mg_2CO_3 solution of concrete cubes. The pH value obtained was 8 alkaline solution .The fc' is 32.33 N/mm^2 or 4619 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
21	36.30	37.28	36.79
42	40.22	40.22	40.22
70	39.24	40.22	39.73
90	35.32	33.35	34.34
120	31.39	29.43	30.41

EFFECT OF CHLORIDES:

Generic Scientific Study/ Discussion : The addition of calcium chlorides reduces initial and final setting time and reduces the curing period and early hardening of concrete .Increase early strength early hardening of concrete .Increase early strength during cold weather and affords resistance to damage by frost action or freezing temperature at early age. An admixture of it reduces the resistance of concrete to sulphate .They chemically increases the expansion caused by AAR and should be avoid with special cement. This increase shrinkage 10%-70% has gradual disintegrating of concrete.

$$Fe^{+2} \text{ ---------- } 2Cl^- \text{ ---------- } FeCl_2$$

$$FeCl_2 + 2H_2O \text{ ---------- } Fe(OH)_2 + 2HCl.$$

Chloride ions present in the cement paste surrounding the reinforcement react with anodic sites to HCl which destroys the passive protective film on the steel. The surface of the steel then becomes activated locally to form the anode, with the passive surface of the cathode, and then ensuring corrosion is the form of localized pitting.

BS 8110: Part 1: 1985 limit of chlorides contents by concrete

Type	Max chlorides contents exposed as %age of chlorides ions in mass of cement
Pre-stressed concrete heat cured containing embedded metal concrete made with sulphate resisting Portland type V cement or sulphated cement	0.1
Concrete containing embedded steel and cement following types used as OPC (type-I)	0.2
Rapid hardening cement (type III) Portland blast furnace (type II) Low heat Portland cement (Type IV) Low heat port land cement (type I,IP) Low heat Portland slag (PFA)	0.4

8.1.1 **ACI 318-83 limit of chlorides contents of concrete**

Types	Max chloride contents expressed as %age of chlorides ions in mass of cement
Pre-stressed concrete	0.06
reinforced concrete exposed chloride in service	0.15
reinforced concrete which will be dry	0.30
other reinforced concrete construction	0.30

$CaCl_2$ in concrete by V.S Ramchadran_: The romans used blood ,pigs fat and milk as additions to Pozzolanic cements to improve the workability and durability. Admixtures are added to water, aggregate and hydraulic cement in before or during mixing. Typical examples water reducers, retarders, water reducing accelerating agents, accelerators and water proofers. An accelerator, in chemical sense accelerate rate of reaction ,physical sense increase in the rate of setting ,in mechanical sense increase in the rate of setting ,in mechanical sense increase in the rate of development of strength .Practical point of view reduced the curing period and reduction in the time during which concrete must be protected in cold weather several chemicals like Calcium formate,$CaCl_2$ is most commonly used are accelerators.

Methods of adding $CaCl_2$: It is recommended that dosage should not exceed 2% by weight of cement .Max 2% flake $CaCl_2$ or 1.5% anhydrous $CaCl_2$.$CaCl_2$ is available as pellets or flakes or in solution form .$CaCl_2$ is soluble in cold or hot water. Add salt to the water. It is (with 77% min $CaCl_2$) or 3.25 pounds of pellet or concentrated flake or other granular form (with 94% min $CaCl_2$) in each gallon of soln. Then add 1 quart of solution/sack of cement when 1% $CaCl_2$ is specified or 2% quarts /sack for 2% $CaCl_2$.Then no water shall be mixed for concrete.

Effect on physical properties of concrete: Calcium chloride significantly reduces both initial and final setting time of concrete. Very excessive amount and even small amount should be avoided. As it rapid set placing and finish may become difficult. SA A266.2-1973 &ASTMC 494-1971 standards initial setting time of 1 hr earlier but not more than 3 hrs for CSA and 3 ½ hrs to ASTM.ASTM says it should be 1 hr earlier than without $CaCl_2$.As it is a accelerator ,it may tend to induce early stiffening thus reduce bleeding .In many instances a whitish deposit on cured concrete is attributed to the presence of $CaCl_2$.When efflorescence does occur it can be removed with dilute HCl, followed by rinsing with water.

Effect of $CaCl_2$ on mechanical behaviour of concrete :Addition of $CaCl_2$ results in accelerated hardening of concrete containing any type of Portland Cement. Amount of $CaCl_2$ in excess of accepted standards cause lowering of strength. Flexural strength does not increase so much as compressive strength with addition of $CaCl_2$.ASTM C-494 show flexural strength at 3 days is 110% but at 3 days compressive strength is 125%.

Chemical effects on concrete :When concrete is exposed to solutions of sulphates react with calcium and aluminum ions in the cement paste to form calcium sulphate and calcium sulphone-aluminate hydrates ,due to $CaCl_2$ the sulphate attack is reduced. Experiments have shown that $CaCl_2$ in concrete aggravates the alkali-aggregates reaction. If $CaCl_2$ has to be used the use of low alkali cement, pozzolaneous or an non-reactive aggregate. Some countries do not recommend the use of $CaCl_2$ in reinforced concrete. <u>$CaCl_2$ is prohibited for pre-stressed concrete</u> .In post-tensioned concrete(wires are encased in tubes) ,it should be used in grout of $CaCl_2$, for steam cured concreting $CaCl_2$ is not recommended for use.

Concluding remarks :There are misconception to the use of $CaCl_2$ as an antifreeze .It is no substitute for good design or poor workmanship or quality material. However ,that <u>calcium chloride is still the most practical accelerator for concrete.</u>

AMMONIUM CHLORIDE

When mixed in water to form concrete:NH_4Cl is available in white solid form. It gives smell.10 cubes were casted after mixing 10% of NH_4Cl by weight of cement. The result shows it has a disintegrative effect when mixed in concrete and this effect depends upon the amount of NH_4Cl used. The deterioration effect of NH_4Cl is more as compared to KCl and $CaCl_2$ and less than that of NaCl .The crushing compressive strength fc' at 28 days used in design is 19.44 MPa or 2778 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
7	15.21	14.72	14.97
30	19.62	20.11	19.87
60	23.54	24.53	24.04
90	27.96	28.94	28.45
120	33.35	31.88	32.62

When applied on concrete surface :-10 cubes were casted after 15 days curing in a solution of NH_4Cl mixed in water and cubes immersed in mixed solution. A pH is 9,slightly basic solution. The fc' is 37.69 MPa or 5384 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
21	38.26	34.34	36.30
42	39.73	41.20	40.47

70	37.28	37.28	37.28
90	39.24	37.28	38.26
120	44.64	41.20	42.92

POTASIUM CHLORIDE : Potassium chloride, KCl , does not chemically attack concrete. It can cause damage in winter from freeze-induced expansion pressure by increasing number of freeze/thaw cycles.

When mixed in water of concrete : It is available in white solid form .It common name is black salt and chemical formula is KCl.We casted 10 cubes after mixing 10 % of KCl by weight ofcement.The results shows that it has a very less disintegrating effect when mixed in water of concrete used and this effect depends upon the KCl used.The fc' is 36.06 MPa or 5151 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
7	30.41	31.39	30.90
30	36.79	36.30	36.55
60	39.24	39.24	39.24
90	41.20	41.45	41.33
120	45.13	46.11	45.62

When applied on concrete surface : Concrete cube specimen immersed in 10% KCl solution immersed for 15 day curing ,shows pH value 9,slightly basic solution.The crushing compressive strength fc' at 28 days is 39.32 MPa or 5618 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
21	41.20	38.26	39.73
42	37.77	39.24	38.51
70	40.22	40.22	40.22
90	38.26	37.28	37.77
120	36.79	37.28	37.04

SODIUM CHLORIDE :

Effect of NaCl when mixed in water (concrete):-It is available in white solid form. Its common name is table salt and chemical formula is NaCl. When 10 cubes casted after mixing 10 % of NaCl by weight of cement. The result shows that with the passage of time the decrease in strength due to the mix of NaCl is significant. Most authorities agrees that NaCl and $CaCl_2$ can cause deterioration to concrete. If good concrete practice are followed, damage can be kept to a minimum. These include using good air-entrained concrete and sealing all cracks. Good surface drainage should be provided and now debris cleaned from gutters during winter. The fc' is 27.921 MPa or 3989 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
7	25.51	26.98	26.25
30	27.47	28.69	28.08
60	33.35	34.34	33.85
90	29.43	28.45	28.94

120	26.00	26.49	26.25

When applied on concrete surface :10 % NaCl solution was immersed in water and cubes casted without NaCl were placed in NaCl included water for 15 days curing shows a pH of 7 ,neutral .The fc' is 35.48 MPa or 5069 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
21	34.34	34.58	34.46
42	36.79	38.26	37.53
70	41.20	39.24	40.22
90	36.30	34.34	35.32
120	33.35	36.30	34.83

CALCIUM CHLORIDE Scientific Discussion : $CaCl_2$ accelerates the hydration of cement ,which reduces initial setting time i.e 45 min , final setting time i.e 10 hrs and shrinkage, while increasing early strength ,surface wear ,cold weather protection and workability .It is used in the manufacturing of ready-mix concrete ,concrete block, pipe, precast products. It is also used by paving contractors, engg . Firms, const companies. When $CaCl_2$ is added to OPC at normal temp of 25 C, it lower's initial setting time from 3 hr to 1 hr and final setting time from 6 hr to 2 hr. It compressive strength at 1 day is more than 50% at 26^0C,3 days compressive strength is 51% higher and at 7days is 32% higher .It also can improve ultimate strength .The Portland cement association found $CaCl_2$ have ultimate strength improvement of 9% in 3 years and California department of public works strength improves by 10 % in 5 yrs.$CaCl_2$ is often added when temperature falls below 19C in the 24 hrs after concrete placement. Its curing lowers evaporation accelerates hydration, which reduces curing.$CaCl_2$ increase concrete flow and workability with same water cement ratio for OPC. It allows greater density by reducing water content upto 0.5 gallon/bag of cement.

When mixed in concrete :It is pungent smell and white solid form, chemical formula is $CaCl_2$.10 cubes after mixing 10 % of $CaCl_2$ by weight of cement. The results show that $CaCl_2$ has no disintegrative effect when mixed in concrete and this effect depends upon the amount of $CaCl_2$ used .It should confirm to requirement ASTM D98 and should be sampled /tested in accordance with ASTM D345.The fc' is 32.562 MPa or 4652 psi.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
7	29.43	29.43	29.43
30	33.35	32.37	32.86
60	45.13	45.62	45.38
90	46.11	45.13	45.62
120	47.09	48.07	47.58

When applied on concrete surface :15 days curing done by adding 10% $CaCl_2$ in water used for curing and 10 cubes casted were immersed in this water ,pH value of 8,slightly basic. It was observed a decrease /same/minor compressive strength observed, but at 90,120 days high surface efflorescence was also observed .The fc' is 34.913 MPa or 4988 PSI .

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
21	35.32	32.37	33.85
42	37.28	36.79	37.04
70	40.22	40.47	40.47
90	39.24	40.22	39.73
120	38.26	37.28	37.77

EFFECT OF SULPHER & PHOSPHOROUS :

Effect of SULPHER when mixed with/in concrete: It is yellow colored powder material which is insoluble in the water. Therefore it was used in the solid form while preparing the concrete mix. Percentage of Sulfur used was 5% by the weight of cement. The fc' is 21.486 MPa or 3069 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
7	19.62	18.64	19.13
30	22.81	20.60	21.71
60	23.79	24.53	24.16
90	25.02	23.79	24.41
120	26.49	24.03	25.26

When applied on surface of concrete :Sulphur is mostly used in the preparing of sulphuric acid. Sulpher is used in paper ,rubber, fertilizers ,explosives and matches industries.10 cubes of plain concrete cubes were immersed in the solution of 5% Sulpher , pH value tested is 7 ,neutral obtained .The fc' is 35.48 MPa or 5069 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
21	34.34	30.41	32.38
42	42.18	41.20	41.69
70	41.20	40.22	40.71
90	42.18	40.22	41.20
120	42.18	45.13	43.66

TRI SODIUM PHOSPHATE :

When mixed in concrete :Cubes were prepared by using 5% of tri sodium phosphate by weight of cement. The fc' is 18.02 MPa or 2574 PSI.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
7	13.73	14.22	13.98
30	17.66	19.13	18.40
60	22.56	21.58	22.07
90	25.51	26.00	25.76
120	26.49	25.51	26.00

When immersed in surface of concrete :After 15 days curing in 5% solution of tri sodium phosphate .10 cubes were cast and immersed in water /tri sodium phosphate for 14 days and tested. The fc' is 33.6 MPa or 4800 PSI.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
21	29.43	31.39	30.41
42	40.22	39.73	39.98
70	42.18	40.22	41.20
90	41.20	38.26	39.73
120	39.24	40.22	39.73

EFFECT OF VEGETABLE & MINERAL OIL:

General scientific study: Many vegetable oils contain free fatty acids cause deterioration of concrete surface. Free animal oils contain acids and cause corrosion .Fish oils are more corrosive than other animal oils. Glycerin attacks concrete. Petroleum oils are harmless to concrete. Common non-mineral oils are cotton seed oils, palm oils, rape seed, olive, linseed ,tang, lard and fish oils. It is assumed that all such oils are dangerous to OPC. For soap and oil seed industry OPC is not recommended for floors. To resist oil attack German recommend use of blast furnace cement or pozzalana, but not immunity to attack. Concrete tanks are used for storage of many oils and suffer attack. A surface coating of sodium silicate and magnesium silico-fluoride are used but in severe condition resin –base coating found satisfactory.

MUSTARD OIL:

Effect of mustard oil when mixed in concrete:Cubes were casted using 7.5% of mustard oil by weight of cement .It was observed that the oil increases the workability. Heavy white crystals were formed on the surface of cubes. Mustard oil reduces the strength of the cubes because oil envelopes the particles of cement and aggregates and as a result binding b/w the particles were not proper resultantly decreases the compressive strength of concrete cubes .The crushing compressive strength fc' is 27.11 MPa or 3873 psi .

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
7	17.66	18.64	18.15
30	27.47	28.45	27.96
60	37.28	37.77	37.53
90	39.24	41.20	40.22
120	42.18	40.71	41.45

When applied on concrete surface:14 days curing simple cubes were immersed in oil. Pure oil was used for observing the effect on surface. There is not much change in compressive strength of cubes. The fc' is 34.50 MPa or 4929 psi.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
21	29.43	34.34	31.89
42	39.24	40.22	39.73
70	38.26	41.20	39.73

90	37.28	36.30	36.79
120	39.24	40.22	39.73

COCONUT OIL:

When mixed in concrete :Cubes were cast using 7.5% of coconut oil by weight of cement .Coconut oil increases the workability but it reduces the strength of cubes. The fc' is 27.11 MPa or 3873 psi.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
7	17.66	18.64	18.15
30	27.47	28.45	27.96
60	37.28	37.77	37.53
90	39.24	41.20	40.22
120	42.18	40.71	41.45

when applied on surface of concrete:Pure coconut oil was used. Same compressive strength achieved as ordinary cubes because the oil are good curing medium. The fc' is 34.50 MPa or 4929 psi .

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
21	29.43	34.34	31.89
42	39.24	40.22	39.73
70	38.26	41.20	39.73
90	37.28	36.30	36.79
120	39.24	40.22	39.73

TURPENTINE :Turpentine has little effect on concrete but considerable penetration occurs. Such oils when continuously split on concrete floors ,often cause gradual deterioration as well as penetration deeply into or even through the concrete .High alumina cement is more resistant.

When mixed in concrete:7.5 % turpentine mixed in water to be used for concrete preparation by weight of cement. The fc' is 30.00 MPa or 4287 psi.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
7	25.51	26.00	25.76
30	32.37	28.45	30.41
60	30.41	28.45	29.43
90	33.35	29.43	31.39
120	30.41	32.37	31.39

On the concrete surface:Pure turpentine oil was used for observing the effect on concrete .There is increase in strength and penetrate more than other oils as viscosity is low.The fc' is 36.10 MPa or 5158 PSI.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
21	31.88	35.32	33.60
42	42.00	40.22	41.11
70	42.18	37.28	39.73
90	48.00	47.00	47.50
120	49.00	50.00	49.50

SOYABEAN OIL:

When mixed in concrete:Cubes were casted using 7.5% soybeans oil by weight of cement. Workability was reduced. The fc' is 15.76 Mpa or 2252 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
7	10.79	11.77	11.28
30	14.72	17.66	16.19
60	18.64	15.70	17.17
90	17.17	17.66	17.42
120	16.68	17.66	17.17

When applied on concrete surface:Pure soybean (vegetable /cooking oil) is applied on cubes of concrete and immersed in water for14 days. It is indicated that soybean has acted as curing medium. The fc' is 36.22 MPa or 5175 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
21	35.32	34.34	34.83
42	38.75	39.24	39.00
70	40.71	42.18	41.45
90	39.24	40.22	39.73
120	39.73	41.20	40.47

MINERAL OIL:Mineral oil such as petrol, fuel oils, petroleum do not attack matured concrete. Lubricating oils do not attack concrete .Concrete floors or mortars joints in brick and tile floors may also be permeable to lighter oil surface treatment with sodium silicate is recommended. In case of petrol, various plastic thin sheet lining are used. The kerosene oil 10% by weight of cement if used will retard against alkalis. Concrete covers to 50-100 mm is recommended for foundation and footing over reinforcement. Construction joint should also be reduced to min. Add protection by the use of chemical resistant stone facing or a layer of plaster of Paris with jute or tar. Petrol oil has no effect on concrete.

KEROSEAN OIL:

When mixed in/with concrete:Cubes casted 10 nos after 10% kerosene oil by weight of cement. At testing the compressive strength is considerable reduced as compared with plain cube of same age. The fc' is 23.36 MPa or 3337 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
7	15.70	16.68	16.19
30	23.54	24.53	24.04
60	29.43	26.49	27.96
90	27.47	29.92	28.70
120	29.43	30.41	29.92

When applied on concrete surface only:-The pure Kerosene oil applied on concrete cubes for 14 days .It was concluded that kerosene oil have lesser effect on surface. The crushing compressive strength at 28 days is fc' is 32.133 MPa or 4591 psi.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
21	31.88	27.47	29.68
42	38.75	35.32	37.04
70	38.26	39.73	39.00
90	37.28	38.26	37.77
120	39.24	36.30	37.77

EFFECT OF MISCELLENEOUS SUBSTANCES:

Organic acids:The organic acids are lactic acid, butyric acid, milk, butter, and acetic acid/vinegar. The 2nd group has as constituents of various oils and fats.

Lactic acid:Acetic acid has most destructive action on set cement. Concrete floor like in diaries, cheese factories also have adverse effect on it. Effluent from dairies contain lactic acid, in treatment plant high alumina cement is used instead of OPC. Acid resisting cements for tile floors in milk processing and bottling rooms are used. Effluent from diaries contain lactic in treatment plants high alumina cement used instead of OPC.

Butyric acid : Seems to have similar actions to lactic acid.

Acetic acid : Attacks set cement and concretes .Pozzolanic and blast furnace slag cements are more resistant than OPC .For weak solution of acetic acid ,acid resistant paints and for strong solution lining are needed.

Tartaric acid:Tartic acid have similar in action like lactic and acetic acid .This is present in fruit juices which required some surface treatment.

Malic acid:Apple juice in which malic acid occurs serious deterioration to OPC and high alumina cement.1% solution can cause serious attack to OPC.

PEPSI:

When mixed in concrete :10 numbers cubes were casted using 20% by weight of cement. The result shows that app 100% decreased in strength versus duration is due to improper bonding due to adding Pepsi. The fc' is 1.46 Mpa or 209 psi.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
7	1.47	1.23	1.35
30	1.47	1.47	1.47
60	2.45	2.21	2.33

90	2.94	3.19	3.07
120	3.43	3.43	3.43

When applied on concrete surface: Pepsi solution cubes were immersed and cured for 14/15 days in water solution. The fc' is 35.32 Mpa or 5045 psi.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
21	34.83	31.39	33.11
42	39.24	40.22	39.73
70	37.28	41.20	39.24
90	44.15	43.16	43.66
120	47.09	46.11	46.60

MANGO JUICE:

When mixed in concrete_: Cubes were casted using 10 % apple juice by weight of cement .Workability was increased and when immersed in water for curing small bubbles were present on surface, shows air-entraining effect. Surface cracks were also produced in the cubes also bonding was not perfect .There is considerable reduction in strength as compared to plain concrete .The fc' is 9.42 Mpa or 1346 psi.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
7	6.50	5.50	6.00
30	10.50	9.00	9.75
60	12.20	10.00	11.10
90	13.00	13.80	13.40
120	13.50	14.50	14.00

When applied on concrete surface: Mango juices solution with 15 days curing were immersed in it .Juice penetrated into concrete which was observed after breaking of cubes. The attack is due to malic acid produced by mango juice. The fc' is 35.64 MPa or 5092 psi.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
21	35.81	33.35	34.58
42	37.28	38.26	37.77
70	39.24	39.73	39.49
90	37.28	40.22	38.75
120	38.26	29.43	33.85

MILK :

When mixed in concrete_:10 numbers cubes were casted after adding 15% by weight of cement. There was 100 % decrease in strength w.r.t plain cubes due to improper bonding due to adding of milk .The fc' was 1.07 MPa or 153 PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
7	0.50	0.98	0.74
30	0.98	1.23	1.10
60	2.45	2.45	2.45
90	2.45	2.94	2.70
120	2.94	3.19	3.07

When applied on concrete surface: Cubes were immersed in milk to see the effect of milk on the surface with 14 days curing. The fc' is 35.32 Mpa or 5046 psi.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
21	34.34	32.37	33.36
42	38.26	40.22	39.24
70	37.28	37.77	37.53
90	36.30	34.34	35.32
120	37.28	35.32	36.30

SUGAR SOLUTION :The effects of sugar depends greatly on the quality used. A small quantity of sugar will act as an acceptable retardar. The delay in setting of concrete is app 4 hrs.It can be used as an admixture.

When mixed in concrete : Cubes were casted using 2.5% of sugar by weight of cement which increases workability .Initial setting time was also increased to 48 hrs .High concentration of sugar can cause drastic decrease in strength. After 30 days cracks were observed. The crushing compressive strength fc' at 28 days was 28.95 MPa or 4136 psi.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
7	20.00	18.00	19.00
30	30.80	29.00	29.90
60	32.80	31.00	31.90
90	45.00	42.00	43.50
120	46.00	44.00	45.00

When immersed in sugar soln of concrete cubes :10% solution of sugar was mixed by weight of cement,15 days curing shows pH value is 8 ,shows slightly alkaline .The crushing compressive strength fc' at 28 days was 37.33MPa or 5334 PSI.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
21	37.00	36.00	36.50
42	40.00	38.00	39.00
70	41.00	38.50	39.50
90	40.00	42.00	41.00
120	42.00	40.50	41.25

GLYCERIN: It is produced in soap manufacturing through free glycerin is not constituent of hard soaps it is usually present in soft soaps .Stronger solution i.e 10% and more have a very destructive effect on concrete .Concentrated glycerin with few %age of water is less destructive.

When mixed in concrete: Cubes were casted by using 10% of glycerin by weight of cement mixed within the concrete .The strength at 7 day were slightly lower and 60,120 days remains almost same. The fc' is 31.81 MPa or 4544PSI.

Age	Compressive Strength(MPa)		
	Cube 1	Cube 2	Average
7	17.66	18.64	18.15
30	32.86	33.35	33.11
60	37.28	38.26	37.77
90	35.32	38.26	36.79
120	39.24	37.28	38.26

When applied on concrete surface: 15 days ordinary cured cubes immersed in liquid having 10 % solution of glycerin with water.10 cubes were casted. The strength almost remain the same. The fc' is 36.5 MPa or 5215 psi.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
21	37.00	35.00	36.00
42	39.00	36.00	37.50
70	38.00	40.00	39.00
90	40.00	42.00	41.00
120	41.00	40.00	40.50

SPIRIT:

When mixed in concrete: Cubes were cast by using 10% spirit by weight of cement mixed within of cement.10 numbers cubes were casted .The strength obtained at 7,30,60,90 and 120 days were sufficiently lower than the plain concrete strength. The fc' is 23.98 MPa or 3425 psi.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
7	14.72	21.58	18.15
30	25.51	23.54	24.53
60	27.47	31.39	29.43
90	28.45	32.37	30.41
120	30.41	29.92	30.17

When applied on concrete surface: 14 days curing concrete cubes were applied 5% solution of spirit with water which gives value of8.0 shows slightly alkaline. The strength at 21,42 days remains same but at 70,90,120 days slightly increase was observed. The fc' is 36.167 MPa or 5167 psi.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
21	36.00	37.00	36.50
42	35.00	36.00	35.50
70	39.00	39.00	39.00
90	40.00	38.00	39.00
120	41.00	42.00	41.50

BLEACHING SOLUTION:

When mixed in concrete:10 numbers cubes casted using 10% by weight of cement. The strength is not much different as compared to plain cement cubes. The fc' is 34.27 Mpa or 4896 psi.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
7	25.00	23.00	24.00
30	36.00	34.50	35.25
60	40.00	42.00	41.00
90	43.00	45.00	44.00
120	46.50	48.50	47.50

When applied on concrete surface: 10 numbers cubes using 3% bleaching solution with water immersed in 14 days of curing concrete cubes having pH is 7.0 , neutral solution .There is not much change in compressive strength .The fc' is 37.92 MPa or 5417 psi.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
21	38.00	36.00	37.00
42	40.00	39.50	39.75
70	39.00	36.50	37.75
90	42.00	41.00	41.50
120	39.24	38.25	38.75

SEWAGE: Domestic sewage is alkaline in nature .When high concentration of sewage used H_2S gas evolved which converts to H_2SO_4 (by oxidation action) by condensation, gradually dissolved and progressive deterioration of concrete take place. Sewage with 150 PPM of SO_4 sulphate salts attack may occur like industrial effluent so cement not more than 8% C_3A content is recommended for use. To retard rate of attack of acid in concrete pipes we may use calcareous aggregate (like stone or dolomite).

When mixed in concrete :Cubes were cast using 10% waste water solution by weight of cement. The strength is much lower w.r.t plain cubes. In this context case should be taken in those areas where there is shortage of water and people tends to use polluted water for constructed purpose. The fc' is 29.24 MPa or 4177 psi.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
7	22.56	21.58	22.07
30	29.43	30.41	29.92
60	26.00	28.94	27.47
90	36.79	38.26	37.53
120	37.28	38.26	37.77

When applied on concrete surface: 10 cubes cured cubes immersed in domestic sewage/waste water. There is not much variation of strength as compared with plain cube. The fc' is 35.56 MPa or 5081 PSI.

Age	Compressive Strength (MPa)		
	Cube 1	Cube 2	Average
21	34.56	36.00	35.28
42	38.26	34.00	36.13
70	37.00	39.00	38.00
90	40.00	41.50	40.75
120	41.00	42.00	41.50

12 VARIOUS PROTECTIVE COATINGS SURFACE TREATMENT:

12.1 Magnesium flousilicate or Zinc Flousilicate :The treatment consists of two or more applications .First a solution of about 1 lb of the fluosilicate crystals per gal of water is used. For subsequent applications about 2 lb of crystals per gal of water is used. Large brushes are convenient for applying on vertical surfaces and mops on horizontals areas. Each application should be allowed to dry after the last one dried, the surface should be brushed and washed with water to remove crystals which have formed. The treatment hardens the surface by chemical action and makes it more impervious .Fluosilicate are available from chemical dealers.

12.2 Sodium silicate/water glass: This is quite viscous and must be diluted with water to secure water penetration ,the amount of dilution depends on the quality of the silicate and permeability of the concrete .Silicate of about 45.4^{0} baumi gravity diluted in proportions of 1 gal with 4 gal of water makes each coat to dry thoroughly. On horizontal surfaces it may be poured on and then spread evenly with brooms or brushes. Scrubbing each coat with water after it has been hardened provides a better condition for application of succeeding coats. For tanks and similar structures, progressively stronger solutions are often used for succeeding coats.

12.3 Drying oils: Boiled or raw linseed oil may be used but the boiled oil dies more rapidly. China wood oil or tung oil and soybean oil are also effective. Applied hot better penetration is secured. The oil should be applied immediately after heating, however, as it will become more viscous if allowed to stand. Two or three coats may be applied, allowing each to dry thoroughly before the next applications. Diluting oil with turpentine ,up to a mixture of equal parts, gives better penetration for first coat. The concrete should be well cured and seasoned before the first application. The oil is sometimes applied after magnesium flousilicate treatment, providing a good coating over a hardened surface.

12.4 Cumar :Cumar is a synthetic resin soluble in xylol and similar hydrocarbon solvents .A solution consists of about 6 lbs of cumar gal of xylol with ½ pt boiled linseed oil makes a good coating. Two or more coats should be applied. Concrete should be fairly dry. The cumar should be powered to aid dissolving .It is available in grades from dark brown to colorless ,and sold through paint and varnish trades.

12.5 **Varnishes & paints** : Any varnish can be applied to the dry concrete .High grade varnishes of the spar, China wood oil, or Bakelite types and synthetic resin paints and coatings, or paints consisting largely of chlorinated rubber or synthetic rubber give good protection against many substances. Two or more coats should be applied. Some manufacturing can supply specially compounded coatings for certain conditions.

12.6 **Bituminous or Coal tar paints ,tar and pitches** :These are usually applied in two coats, a thin priming coat to ensure bond and a thicker finish coat .Finish coat must be carefully applied to secure continuity and pinholes. Surface should be touched up when necessary.

12.7 **Bituminous enamel**:This is suitable protection against acids. It does not resist abrasion at high temperatures. Two materials are used, a priming solution and the enamel proper .The priming solution is of thin brushing consistency and should be applied so as to completely cover, touching up any un-coated spots before applying the enamel. When the primer has dried to a tacky state, it is ready for the enamel. The enamel usually consists of bitumen with finely powered siliceous mineral filler. The enamel should be melted and carefully heated until it is fluid enough to brush .The temperature should not exceed 375^{0}F/141 ^{0}C.When fluid it should be mopped on quickly, as it sets and hardens rapidly.

12.8 **Bituminous Mastic**: This is used chiefly for floors on account of the thickness of the layer which must be applied, but some mastic can be toweled on the vertical surfaces. Some mastics are applied cold. Others must be heated until fluid. The cold mastic consists of two compositions the priming solution and the body coat or mastic .The primer is first brushed on. When the primer has dried to a tacky state, a thin layer about 1/32 in of the mastic is toweled on. When this has dried –successive 1/32 in coat of the mastic are applied until they required thickness has been built up. The mastic is similar to the primer but is ground with sufficient asbestos and finely powered siliceous material fillers to make a thick pasty fibrous mass. The hot mastics are somewhat similar to the mixtures used in sheet asphalt pavements ,but contain more asphaltic binder so that when heated to fluid conditions they can be poured and toweled into place. They are satisfactory only when supplied in layers 1 inch or more in thickness .When ready to lay, the mixture usually consists of about 15% asphaltic binder,20% finely powered siliceous mineral filler, and the remainder is sand graded up to ¼ in maximum size.

12.9 **Vitrified brick or tile**: These are special burnt clay products which possess high resistance to attack by acids or alkalis .They must, of coarse, be laid in mortar which is also resistant against the substance to which they are to be exposed. A water proof membrane and a bed of mortar are usually placed between the brick or tile and concrete. Some of the acid resist cements are melted and poured in the joints .Only materials suitable for the conditions should be used and the manufacturer's directions for in stallion must be followed. Silica brick and cement are not resistant to the hydrofluoric acid and the hydroxides, but special brick and cement for these substances are available.

12.10 **Glass**: May be cemented to concrete.
12.11 **Lead**: May be cemented to the concrete with an asphalt paint.
12.12 **Sheets of synthetic resin, rubber resistant to many acids, alkalies and other substances are available**. These are cemented to concrete with special adhesives.

Effect due to various materials and proposed surface treatment(Table)

Material	Effect on Concrete	Surface Treatment
	Acids	
Acetic	Disintegrates slowly	12.5,12.6,12.7

Acid waters	Natural acid waters may enode surface mortar,but usually action then stopes	12.1,12.2,12.3
Carbolic	Disintegrates slowly	12.1,12.2,12.3,12.5
Carbonic	Disintegrates slowly	12.2,12.3,12.4
Humic	Depends on humus material,but may cause slow disintegrates	12.1,12.2,12.3
Hydrochloric	Disintegrates	12.8,12.9,12.10,12.11, 12.12
Hydrofluoric	Disintegrates	12.8,12.9,12.11,12.12
Lactie	Disintegrates slowly	12.3,12.4,12.5
Muriatic	Disintegrates	12.8,12.9,12.10,12.11, 12.12
Nitrie	Disintegrates	12.8,12.9,12.10,12.11, 12.12
Oxalic	None	None
Phosphoric	Attacks surface slowly	12.1,12.2,12.3
Sulfuric	Disintegrates	12.8,12.9,12.10,12.11, 12.12
Sulfurous	Disintegrates	12.8,12.9,12.10,12.11, 12.12
Tannie	Disintegrates slowly	12.1,12.2,12.3
Salts and Alkalies (solutions)		
Carbonates of ammonia ,potassium ,sodium	None	None
Chlorides of calcium,potassium, sodium, stronium	None unless concrete is alternately wet and dry with the soln ,when it is advisable to treat with	12.1,12.2,12.3
Chlorides of ammonia ,copper,iron, magnesium,mercury,sinc	Disintegrates slowly	12.1,12.3,12.4
Fluorides	None except amonium fluoride	12.3,12.4,12.5
Hydroxides of ammonia,calcium, potasium, sodium	None	None
Potassium permangante	None	None
Silicates	None	None

Sulfates of ammonia	Disintegrates	12.6,12.7,12.8,12.9
Aluminum,calcium,cabalt, copper,iron,manganese,nickel, potassium,sodium, zinc	Disintegrates; however ,concrete products cured in high pressure steam are highly resistant to sulfates	12.1,12.3,12.4
Petroleum oils		
Heavy oils below 35 baume	None	None
Light oils above 35 degree bauma	None require impervious concrete to prevent loss from pentration ,surface treatment are generally used	12.1,12.2,12.3,12.5,12.9
Benzine,gasoline,kerosene ,naphta	None require impervious concrete to prevent loss from penetration ,surface treatment are generally used	12.1,12.2,12.3,12.5,12.9
Nigh-octane gasoline		12.12
Coal –tar distillates		
Aizarin,anthracene,benzol ,cumol, paraffin,pitch,tolrol,xylol	None	None
Creosote,cresol, phenol	Disintegrate slowly	12.1,12.2,12.5,12.9
Vegetable oils		
Cottonseed	No action if air is excluded Slight disintegrating if exposed to air	None 12.1,12.2,12.5,12.9
Rosin	None	None
Almond,castor, Chinawood,coconut,linseed,oilive, peanut,poppy seed,rapeseed soyabean,tung, walnut	Disintegrates surfaces slowly	12.1,12.2,12.5,12.9
Turpentine	None-considerable penetration	12.1,12.2,12.5,12.9
Fats and fatty acids(animals)		
Fish oil	Most fish oils attack concrete slightly	12.1,12.2,12.3,12.5,12.9
Foot oil,lard and lard oil,tallow and tallow oil.	Disintegrates surface slowly	12.1,12.2,12.3,12.5,12.9
Miscellaneous		
Alcohol	None	None

Ammonia water(ammonium hydroxide)	None	None
Baking soda	None	None
Beer	Beer will cause no progressive disintegration of concrete,but in beer storage and fermenting tanks a special coating is used to guard against contaminationof beer.	Coatings made and applied by turner rostock Co. 420 lexington Ave,New york and borsari tank corp of Amercia,60 E 42d St New Yark
Bleaching solution	Usually no effect.Where subject to frequent wetting and drying with soln. containing calcium chloride provide	12.1,12.3,12.4
Borax,boracic acid,boric acid	No effect	None
Brine(salt)	Usually no effect on impervious concrete.Where subject to frequent wetting and drying of brine provide	12.1,12.2,12.3
Buttermilk	Same as milk	12.3,12.4,12.5
Charged water	Same as carbonic acid-slow attack	12.1,12.2,12.3
Caustic soda	None	None
Cider	Disintegrates(see acetic acid)	12.5,12.6,12.7
Cinders	May cause some disintegrating	12.1,12.2,12.3
Coal tar distillates	Great majority of structures show no deterioration.Exceptional cases have been coal high in pyrites(sulfide of iron) and moisture showing some action but the rate is greatly retarded by deposit of an insoluble film.Action may be stopped by surface treatments	
Corn syrup	Disintegrates slowly	12.1,12.2,12.3
Cyanide solutions	Disintegrates slowly	12.7,12.8,12.9,12.10,12.12
Electrolyte	Depends on liquid.For lead and zinc refining and chrome plating use nickel and copper plating	12.7,12.8,12.9,12.10,12.11
Formalin	Aqueous soln. of formaldehyde disintegrates concrete	12.5,12.9,12.10,12.11,12.12
Fruit juices	Most fruit juices have little if any effect as tartaric acid and citric acid acid do not appreciably affect concrete .Floors under raisin seeding machines have shown some effect,probably due to poor concrete	12.1,12.2,12.3
Glucose	Disintegrates slowly	

Clycerin	Disintegrates slowly	12.1,12.2,12.3,12.4, 12.5,12.9
Honey	None	None
Lye	None	None
Milk	Sweet milk should have no effect,butif allowed to sour te lactic acid will attack	12.3,12.4,12.5
Molasses	Does not affect impervious,thoroughly cured concrete ,Dark,partly refined molasses may attack concrete that is not thoroughly cured.Such concrete may be protected with	12.2,12.5,12.9
Niter	None	None
Sal ammoniac	Same as ammonium chloride-causes slow disintegration	12.1,12.2,12.3
Sal soda	None	12.1,12.2,12.3
Saltpeter	None	None
Sauerkraut	Little,if any,effect.Protect taste with	12.1,12.2
Silage	Attacks concrete slowly	12.3,12.4,12.5
Sugar	Dry sugar has no effect on concrete that is thoroughly cored	None
Sulfide liquor	Attacks concrete slowly	12.1,12.2,12.3
Tanning liquor	Depends on liquid .Most of them have no effect .Tanneries using chromium report no effects.of liquid is acid,protect with	
Trisodium phosphate	None	None
Vinegar	Disintegrates	12.5,12.6,12.7
Washing soda	None	None
Whey	The lactic acid will attack concrete	12.3,12.4,12.5
Wine	Many wine tanks with no surface coatings have given good results but taste of first batch may be affected unless concrete has been given tartic acid treatment	For fine wines the concrete has been treated with 2 or 3 applications of tartic acid soln (1 lb tartic acid soln 3 lb water)sodium silicate is also effective in a few cases tanks havebeenlined with been lined with glass tile.
Wood pulp	None	None

Summary:
Concrete's durability is compromised by exposure to various chemicals, either during mixing or post-curing. This research outlines mechanisms of deterioration and mitigation strategies for accidental materials, addressing both scenarios: mixing contaminants into concrete and post-curing immersion. Concrete degradation due to accidental

materials involves complex chemical, physical, and biological interactions. This study dives deeper into **mechanisms of deterioration** and **advanced mitigation strategies**, addressing both **contamination during mixing** and **post-curing exposure**. Emphasis is placed on material science, chemical interactions, and innovative technologies.

Accidental materials such as acids, sulphates, chlorides, carbonates, salts, alkalis, petroleum oils, vegetable oils, and miscellaneous substances (juices, sugar solutions, sewage, Pepsi, etc.) can significantly deteriorate the strength, durability, and integrity of concrete. Their impact varies from corrosion of reinforcement, loss of bonding, delayed hydration, expansion, cracking, and surface degradation.

To mitigate these effects, a combination of preventive and remedial measures is essential. The use of specialized cement types (e.g., sulphate-resistant and low-alkali cement), pozzolanic materials (fly ash, silica fume, GGBS), protective coatings (epoxy, polyurethane), and chemical inhibitors (corrosion and ASR inhibitors) can enhance concrete resistance. Additionally, reducing permeability through a low water-cement ratio and proper curing ensures long-term durability.

Proper material selection, maintenance, and protective strategies are key to extending the service life of concrete structures exposed to these accidental materials. Future research should focus on innovative admixtures, nanomaterials, and self-healing concrete technologies to further enhance resistance against chemical attacks and environmental hazards.

Mitigation requires a dual approach: **preventive mix design** and **post-curing protections**. Future research should explore nanomaterials and bio-based inhibitors for enhanced durability. Standards like ACI 318 (sulfate resistance) and EN 206 (carbonation) provide foundational guidelines.

Mitigating accidental material impacts requires **multi-scale strategies**, from nano-engineered additives to macro-scale coatings. Future advancements lie in **smart materials**, **biotechnology**, and **sustainability-driven designs**. Standards like **ACI 201.2R** (durability) and **ISO 1920** (testing) provide frameworks, but innovation must bridge lab research to field applications.

A. **Acids (e.g., HCl, H_2SO_4, Organic Acids, HCl, H_2SO_4)**

- **Effects When Mixed**: Lowers pH, disrupting cement hydration, reducing strength. Acid attacks dissolve cement paste, weaken concrete, and cause surface erosion
- **Effects When Immersed**: Dissolves calcium hydroxide (CH), causing surface erosion.
- **Remedial Measures**:
  - **Mixed**: Neutralize acid with lime pre-mixing; use pozzolans (fly ash, silica fume) to reduce CH.
  - **Immersed**: Apply acid-resistant coatings (epoxy, polyurethane); use high-density concrete with low water-cement (w/c) ratio.
  - **Mechanisms of Attack**:
  - **Mixed**: Acids lower the pH of the concrete matrix (<4), dissolving portlandite ($Ca(OH)_2$) and C-S-H gel, leading to loss of cohesion.
  - **Immersed**: Acidic solutions leach calcium, forming soluble salts (e.g., $CaCl_2$, $CaSO_4$) and creating porous, weakened surfaces.
  - **Advanced Mitigation**:
  - **Mix Design**:
  - **pH Buffering**: Incorporate **calcium carbonate (limestone)** aggregates to
  -
  - Neutralize acids via: CaCO3+2H+→Ca2++CO2+H2OCaCO3+2H+→Ca2++CO2+H2O.
  - **Alternative Binders**: Use **geopolymers** (alkali-activated aluminosilicates) resistant to pH < 3.
  - **Pozzolans**: High-reactivity silica fume (10–15% cement replacement) reduces CH content, minimizing acid-soluble phases.
  - **Post-Curing Protection**:
  - **Acid-Resistant Liners**: Apply **fluoropolymer coatings** (e.g., PTFE) or **vitrified tiles** for sustained chemical resistance.
  - **Surface Treatments**: **Sodium silicate densifiers** reduce permeability by sealing pores.

- **Case Study:** Sewage pipelines use **epoxy-coated concrete** to resist biogenic sulfuric acid (H_2SO_4) from bacterial activity.

 Mitigation:

- Use acid-resistant cement (e.g., calcium aluminate cement).
- Apply protective coatings (epoxy, polyurethane).
- Increase concrete density by reducing water-cement ratio.
- Add pozzolanic materials (fly ash, silica fume) to improve chemical resistance.
- Use polymer-modified concrete or geopolymer concrete.

B. Sulphates (e.g., Na_2SO_4, $MgSO_4$)

- **Effects:** Expansive ettringite formation, cracking. Sulphate attack leads to expansion, cracking, and strength loss.
- **Remedial Measures:**
  - **Mixed:** Sulfate-resistant cement (Type V); limit gypsum content.
  - **Immersed:** Low w/c ratio; pozzolans to reduce CH and alumina.

  Mechanisms:
- **Ettringite Formation:** Sulfates react with calcium aluminate hydrates to form expansive ettringite ($3CaO \cdot Al_2O_3 \cdot 3CaSO_4 \cdot 32H_2O$), causing cracking.
- **Gypsum Formation:** Secondary reaction produces gypsum ($CaSO_4 \cdot 2H_2O$), leading to softening.
- **Mitigation:**
- Use sulphate-resistant cement (Type V or SRPC).
- Reduce permeability with pozzolanic admixtures (silica fume, GGBS).
- Ensure proper curing and low water-cement ratio.
- Apply water-repellent coatings in sulfate-rich environments.

Advanced Mitigation:

1. **Mix Design:**
   - **Sulfate-Resistant Cement (Type V):** Limits C_3A content (<5%) to minimize ettringite formation.
   - **Blended Cements:** Use **slag** or **metakaolin** (20–40% replacement) to bind alumina and reduce reactive phases.
2. **Post-Curing:**
   - **Crystallization Inhibitors:** Add **barium nitrate** ($Ba(NO_3)_2$) to precipitate sulfates as non-expansive $BaSO_4$.
   - **Hydrophobic Agents: Silane-siloxane** treatments block sulfate ion ingress.

   Research Insight: Blending **nano-clay** (2–5%) with cement reduces sulfate permeability by 40% due to pore refinement.

C. Chlorides (e.g., NaCl, $CaCl_2$)

- **Effects:** Rebar corrosion via chloride ingress. Causes corrosion of reinforcement, leading to cracking and structural failure.
- **Remedial Measures:**
  - **Mixed:** Corrosion inhibitors (calcium nitrite); stainless steel rebar.
  - **Immersed:** Silane coatings; cathodic protection; low-permeability concrete.

Mechanisms:

- Rebar Corrosion: Chlorides penetrate concrete, depassivate steel, and initiate pitting corrosion: Fe+2Cl−→FeCl2+2e−Fe+2Cl−→FeCl2 +2e−.
- Freeze-Thaw Damage: Chlorides lower pore solution freezing points, increasing internal stress.

Mitigation:

- Use corrosion inhibitors (e.g., calcium nitrite).
- Apply protective coatings on rebars (epoxy, zinc coating).
- Increase cover thickness of reinforcement.

- Use low-permeability concrete with pozzolanic additives.
- Use non-chloride-based accelerators in concrete mix.

Advanced Mitigation:

1. **Mix Design:**
    - Corrosion Inhibitors: Organic inhibitors (e.g., amines, ethanolamines) form protective films on steel.
    - Cathodic Protection Integration: Embed conductive carbon fibers (1–2% by volume) for distributed cathodic protection.
2. **Post-Curing:**
    - Electrochemical Chloride Extraction (ECE): Apply a direct current to extract Cl^- ions.
    - Self-Healing Concrete: Use microencapsulated sodium silicate to seal cracks and block chloride ingress.

Innovation: Graphene oxide (0.03–0.1% by weight) enhances chloride resistance by 60% via pore-blocking and electrical conductivity modulation.

D. Carbonates (CO_3^{2-})

- **Effects**: Carbonation reduces pH, enabling corrosion. Carbonation reduces alkalinity, increasing corrosion risk
- **Remedial Measures**:
    - **Mixed/Immersed**: Increase concrete cover; use silica fume; apply anti-carbonation coatings.

  Mechanisms:
    - **Carbonation**: CO_2 diffuses into concrete, reacting with CH: $Ca(OH)2+CO2 \rightarrow CaCO3+H2OCa(OH)2+CO2 \rightarrow CaCO3+H2O$. Lowers pH to ~8–9, enabling steel corrosion.

  Mitigation:
- Use high-performance concrete with low permeability.
- Apply carbonation-resistant coatings.
- Ensure adequate concrete cover for reinforcement.
- Use blended cements with pozzolans to reduce carbonation rate.
    - **Advanced Mitigation**:
    - **Mix Design**:
    - **Low-Cement Blends**: Replace cement with **slag** (50–70%) to reduce CH content.
    - **Alkali Reservoirs**: Add **potassium carbonate** (K_2CO_3) to maintain high pH.
    - **Post-Curing**:
    - **Photocatalytic Coatings**: Use **TiO_2 nanoparticles** to decompose CO_2 under UV light.
    - **Anti-Carbonation Membranes**: **Acrylic-based coatings** with CO_2 diffusion resistance <0.5 g/m²/day.
    - **Research Frontier**: **Bio-concrete** with *Bacillus pseudofirmus* bacteria precipitates $CaCO_3$ to self-seal carbonation-induced cracks.

E. Salts and Alkalis (e.g., Na^+, K^+) and Alkali-Silica Reaction (ASR)

- **Effects**: Alkali-silica reaction (ASR) causing expansion and cracking.
- **Remedial Measures**:
    - **Mixed**: Low-alkali cement; lithium-based admixtures.
    - **Immersed**: Non-reactive aggregates; pozzolans (slag, metakaolin).
- **Mechanisms**:
- **ASR Gel Formation**: Alkalis react with reactive silica in aggregates, forming expansive alkali-silica gel: $SiO2+2NaOH \rightarrow Na2SiO3+H2OSiO2+2NaOH \rightarrow Na2SiO3+H2O$.

Mitigation:

- Use low-alkali cement (<0.6% Na_2O equivalent).
- Add pozzolanic materials (fly ash, metakaolin) to mitigate ASR.
- Use lithium-based ASR inhibitors.
- Avoid reactive aggregates.
- **Advanced Mitigation**:

- **Mix Design**:
- **Lithium-Based Admixtures**: $LiNO_3$ suppresses ASR by forming non-expansive Li–Si compounds.
- **Non-Reactive Aggregates**: Use **quartzite** or **limestone** with low silica content.
- **Post-Curing**:
- **Lithium Silicate Treatments**: Penetrate concrete to neutralize residual alkalis.
- **Pore-Blocking Nanogels**: **Silica aerogels** reduce alkali mobility.
- **Case Study**: The **Three Gorges Dam** used lithium nitrate admixtures to prevent ASR in high-alkali environments.

F. Sulfur and Phosphates

- **Effects**: Sulfur oxidizes to H_2SO_4; phosphates form weak complexes. Sulfur weakens concrete by forming ettringite, while phosphates reduce hydration
- **Remedial Measures**:
    - **Mixed**: Use limestone aggregates to buffer acidity.
    - **Immersed**: Geopolymer concrete; phosphate-resistant coatings.

Mitigation:

- Use sulphate-resistant cement and pozzolans.
- Apply surface sealers to prevent penetration.
- Control pH of mixing water to neutralize phosphate effects.

G. Petroleum/Vegetable Oils Diesel, Gasoline, Engine Oils)

- **Effects**: Soften concrete; hinder hydration. Delays hydration, weakens bonding, and reduces strength. Interferes with hydration and causes surface weakening.
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- **Remedial Measures**:
    - **Mixed**: Surfactants to disperse oil; increase cement content.
    - **Immersed**: Hydrophobic admixtures (oleophobic coatings).

  Mechanisms:
- **Hydration Disruption**: Oils coat cement particles, delaying C_3S and C_2S hydration.
- **Pore Clogging**: Hydrophobic oils block moisture movement, causing uneven curing.
- **Advanced Mitigation**:
- **Mix Design**:
- **Emulsifiers**: **Polycarboxylate ethers** disperse oil droplets, allowing hydration.
- **Oil-Resistant Binders**: **Magnesium oxychloride cement** (MOC) resists oil penetration.
- **Post-Curing**:
- **Superhydrophobic Coatings**: **Fluoroalkylsilane** coatings create contact angles >150°, repelling oils.
- **Thermal Treatment**: Heat contaminated concrete to 300°C to volatilize oils (limited to non-reinforced elements).
- **Innovation**: **Carbon nanotube-reinforced concrete** resists oil penetration due to its ultra-high density.

Mitigation:

- Wash aggregates before mixing.
- Use chemical degreasers before repairs.
- Apply sealers to prevent penetration.
- Use polymer-modified concrete in oil-exposed areas.
- Ensure proper water-cement ratio.
- Use oil-absorbing aggregates or surfactants.
- Wash surfaces before further concrete applications.

H. Miscellaneous (Juices, Sewage, Pepsi)

- **Effects**: Sugars retard setting; sewage biogenic H_2SO_4. Sugars retard cement hydration, while organic acids degrade surface.
- **Remedial Measures**:
    - **Mixed**: Accelerators ($CaCl_2$) counteract sugar; pre-treat sewage.
    - **Immersed**: Antimicrobial additives; epoxy linings for sewage.

  Mechanisms:
- **Sugars (Juices, Pepsi)**: Sucrose adsorbs onto C_3S, inhibiting nucleation of hydration products.
- **Sewage**: Sulfate-reducing bacteria produce H_2S, oxidizing to H_2SO_4.

Mitigation:

- Use retardation-resistant cement types.
- Wash aggregates and reinforcements before use.
- Use high-performance concrete with silica fume.
- Ensure proper drainage and cleaning in sewage-exposed areas.

Advanced Mitigation:

1. **Mix Design:**
   - **Biocidal Agents: Zinc oxide nanoparticles** (1–3%) inhibit microbial growth in sewage-exposed concrete.
   - **Accelerators: Triethanolamine** (0.1–0.5%) counteracts sugar-induced retardation.
2. **Post-Curing:**
   - **Enzyme-Based Cleaners: Urease-producing bacteria** degrade organic contaminants.
   - **Antimicrobial Photocatalysts: TiO_2/Ag nanocomposites** under UV light degrade organics and kill bacteria.

Case Study: Tokyo's sewer systems use **HDPE-lined concrete** to resist biogenic acid corrosion.

3. General Mitigation Strategies

- **Mix Design:** Low w/c ratio, SCMs (fly ash, slag), corrosion inhibitors.
- **Coatings:** Epoxy, polyurethane, silane for chemical resistance.
- **Curing:** Proper moisture retention to reduce permeability.
- **Advanced Methods:** Geopolymers, nanotechnology sealers, cathodic protection.
- **3. Cutting-Edge Mitigation Technologies**
- **Nanomaterials:**
- **Nano-SiO_2:** Fills nano-pores, reducing permeability by 50%.
- **Graphene:** Enhances tensile strength and chloride resistance.
- **Self-Healing Systems:**
- **Microbial Capsules:** *Sporosarcina pasteurii* heal cracks via $CaCO_3$ precipitation.
- **Shape-Memory Polymers:** Close cracks upon thermal activation.
- **Digital Monitoring:**
- **Embedded Sensors:** Fiber-optic sensors track pH, Cl^-, and crack propagation in real time.
- **4. Future Research Directions**
- **Bio-Inspired Materials:** Mimic mollusk shells for layered, acid-resistant structures.
- **AI-Driven Mix Optimization:** Machine learning models to predict durability under multi-contaminant exposure.
- **Circular Economy:** Use industrial byproducts (e.g., red mud, rice husk ash) for low-cost, high-performance concrete.

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