A Study on Influence of Phosphogypsum on Durability of the Conctere

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Abstract – Cement consumption in any country is directly related to the country's infrastructure sector and thus growth in determining the development of the country. World demand for cement is projected to rise 4.5% per year to 5.2 billion metric in 2019.India is the second largest producer of cement in the world. Cement has a negative impact over Environmental, because at the time of manufacturing it emits about a ton of greenhouse gas (CO_2) into the atmosphere for every ton of cement manufactured. Production of Portland cement not only releases 7% of the World's carbon dioxide, the cement industry also uses a lot of natural resources such as limestone, clay, petroleum, coal and other substances to preserve the natural resources and to reduce the pollution due to the production of cement is by limiting the cement content in the concrete without compromising the strength. There were efforts before to partially replace cement in concrete with new compounds and industry by-products.

Phosphogypsum is a by-product of phosphate fertilizer plants and chemical industries for manufacture of phosphoric acid by the action of sulphuric acid on the rock phosphate. It can be gainfully utilized in cement and building materials industries. It needs beneficiation before use because of the presence of deleterious constituents like P_2O_5 and fluoride. The disposal of phosphogypsum is a serious environmental problem. This problem along with scarcity of cement, and its increased cost can be solved to some extent by partial replacing the cement in concrete with phosphogypsum. Due to its pozzolonic properties it can be used for partial replacement of cement.

The present paper deals with the experimental investigation on compressive strength, tensile strength, impact strength and durability characteristics of hardened concrete. The study aims to determine the optimum amount of phosphogypsum that can give maximum strength to the concrete. The experiment consists of testing concrete using 0%, 2.5%, 7.5%, 5%, and 10% replacement of phosphogypsum for M_{20}, M_{25}, and M_{30} grades of concrete. It is observed that cement can be replaced with phosphogypsum to develop to good and hardened concrete to achieve economy.

Index Terms – Phosphogypsum, Strength of Concrete, Durability; Acids (H_2So_4), Base (Nacl).

INTRODUCTION

Traditionally materials like clay, sand, gravels, cement, stone, brick, block, tiles, paint, timber, and steel are being used as major building components in construction sector. All these materials have been produced from the existing natural resources and will have intrinsic distinctiveness for damaging the environment due to continuous exploration. In India the cost of cement during 1996 was Rs. 1.25/kg and in 2016 the price increased 5 times. In case of bricks the price was Rs. 0.56 per brick in 1996 and the present rate is Rs.7 per brick. Similarly, the price of sand has increased 6 times over a period of 20 years from the year 1996. Due to this find functional substitutes for conventional materials in construction industry.

In India, about 6 MT of waste gypsum such as phosphogypsum, flurogypsum etc., are being generated annually. It is necessary to set a secondary industries and recycling these waste into useful material. In the country produce nearly 4 to 5 MT of phosphogypsum as by-product about 12 fertilizer plants. Major producers are coromandel fertilizers (Andhra Pradesh), Gujarat state fertilizer Co. (Gujarat), Hindustan lever Ltd. (West Bengal), southern petrochemical industries corporation (Tamil Nadu) and Paradeep Phosphates Ltd. (Orissa).

Handling and disposal of phosphogypsum is not only a serious techno-economic problem but creates environmental pollution and requires large area for dumping. So by using phosphogypsum as a substitute for conventional material problem of dumping waste can be solved in eco-friendly manner.

GENERATION OF PHOSPHOGYPSUM

Phosphogypsum generation in India is about 11 Million ton per annum. Nearly 5 tones of phosphogypsum generated per ton of phosphoric acid production. Phosphogypsum is generated from filtration process in phosphoric acid plants. Depending on the source of phosphate rock about 4.5-5 tones of phosphogypsum is generated per ton of phosphoric acid recovered.

The quality and quantum of phosphogypsum generation depends upon the quality of the phosphate rock, process route used to produce phosphoric acid, calcium sulphate generated either in di-hydrate ($CaSO_4.2H_2O$) or the hemi-hydrate ($CaSO_4.1/2\ H_2O$) form.

The production of phosphoric acid and estimated phosphogypsum scenario in the country as per the information provided by the fertilizer units is compiled and given in table below.

Table1: estimated generation of phosphogypsum

year	Phosphoric acid production*	Estimated Phosphogypsum generation**
2000-01	1042.4	4690.8
2001-02	1134.7	5106.15
2002-03	1085.6	4885.2
2003-04	990.1	4455.45
2004-05	1242.5	5591.25
2005-06	1067.8	4805.1
2006-07	1331.8	5993.1
2007-08	1206.5	5429.25
2008-09	1201.7	5407.65
2009-10	1160	5407.65
2010-11	1544.6	5220
2011-12	1740.4	6950.7
2012-13	1394.7	6276.15

Fig: Phosphogypsum

Phosphoric acid is expressed as 100% P2O5 plaster developed from this phosphogypsum has showed improved engineering properties without any harmful effect. Phosphogypsum were recycled for manufacture of Portland cement, masonry cement, sand lime bricks, partition walls, flooring tiles, blocks, gypsum plaster, fibrous gypsum boards and super sulphate cement. Phosphogypsum could also be used as a soil conditioner for calcium and sculpture deficient soils and it also has fertilizer value due to the presence of ammonium sulphate.

MATERIAL PROPERITIES

Concrete is a development material made out of Portland cement, sand, aggregate and water. In addition to its potential for compressive strength and its ability, when poured, to adapt to virtually any form, concrete is fire-resistant and has become one of the most common building materials in the world.

ORDINARY PORTLAND CEMENT

Portland cement is the most common type of cement in general use all around the world. It is used as a basic ingredient of concrete. Several types of port land cement are available in market. The specific gravity of cement is 3.14.

FINE AGGREGATE

Fine aggregate/sand is an aggregation of grains of mineral matter got from the breaking down of rocks. The fine total was going through 4.75 mm strainer and the evaluating zone of fine total was zone II according to Indian Standard particulars e grains or particles, yet it is unmistakable from dirt's which contain natural materials. Specific Gravity-2.75, Fineness Modulus-2.8

COARSE AGGREGATE

Coarse Aggregates are the pulverized stone is utilized for making concrete. The stone is quarried, pounded and evaluated. Machine smashed rock softened stone precise up shape was utilized as coarse aggregate was 20 mm and Specific Gravity-2.63, Fineness Modulus-7.2

WATER

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully.

PHOSPHOGYPSUM

The physical properties of the phosphogypsum as follows:

- Color : gray
- Particle size : 0.5 mm (No. 40 sieve) and 1.0 mm (No. 20 sieve) and majority of the particles (50-75%) are finer than 0.075 mm (No. 200 sieve).
- Specific gravity : 2.3 - 2.6
- Dry bulk density : 1470 -1670 kg/m^3
- Moisture content : 25 -30 %

Phosphogypsum consists of primarily of calcium sulphate dehydrate with small amount of silica, usually as quartz and unreacted phosphate rock, radioactive material (like radium, uranium), heavy metals namely arsenic, cadmium, chromium, mercury, and fluoride. The concentration of the metals depends on the composition of the phosphate rock.

Typical chemical characteristics of the phosphogypsum are given in table 2.

Table: chemical characteristics of the phospogypsum

Chemical Constituents	Percentage (%)
CaO	31.2
SiO_2	3.92
SO_2	43.3
Fe_2O_3	1.82
MgO	0.49
Organic matter	0.26
Na_2O	0.36
P_2O_5	0.5

CONCRETE MIX DESIGN

Table: Mix Proportion for M_{20}

Cement (Kg/m^3)	Fine aggregate(Kg/m^3)	Coarse aggregate(Kg/m^3)	Water(lit/m^3)
1	1.51	3.13	0.5
383	579.50	1200	191.58

Table: Mix Proportion for M_{25}

Cement (Kg/m^3)	Fine aggregate(Kg/m^3)	Coarse aggregate(Kg/m^3)	Water(lit/m^3)
1	1.38	2.86	0.48
411.11	568.47	1177.50	197.33

Table: Mix Proportion for M_{30}

Cement (Kg/m^3)	Fine aggregate(Kg/m^3)	Coarse aggregate(Kg/m^3)	Water(lit/m^3)
1	1.23	2.56	0.45
449.46	555.97	1151.41	202.39

EXPERIMENTAL RESULTS:

WORKABILITY OF CONCRETE

Workability of concrete is defined as the amount of useful internal work necessary to produced 100% compaction. It is also defined as the ease with and homogeneity with which a freshly mixed concrete or mortar can be mixed, placed, compacted and placed. It is the wetness of the concrete of the concrete and measure of fluidity or mobility.

Wet concretes are more workable than dry concretes of the same consistency may vary in workability. A concrete which has high consistency and which is more mobile, need not be of right workability for a particular job. Type of the work, thickness of section, reinforcements and mode of compaction are the aspects to be considered while specifying the workability for any particular job.

DURABILITY OF CONCRETE

Durability of Concrete is defined as the ability to resist weathering action and chemical attack, while maintaining the desired engineering properties. Due to the use of inappropriate materials, poor construction practices, insufficient curing, and/or improper mix designs, many structures show serious premature deterioration. The durability in

1) Durability Acid (H2So4) Test

2) Durability Base (Nacl) Test

1. DURABILITY ACID TEST:

The concrete cube specimens of various concrete mixtures of size 150 mm were cast and after 28 days of water curing, the specimens were removed from the curing tank and allowed to dry for one day. The weights of concrete cube specimen were taken. The acid attack test on concrete cube was conducted by immersing the cubes in the acid water for 90 days after 28 days of curing. Sulphuric acid (H2so4) with pH of about 2 at 5% weight of Water was added to water in which the concrete cubes were stored. The pH was maintained throughout the period of 90 days. After 90 days of immersion, the concrete cubes were taken out of acid water. Then, the specimens were tested for compressive strength. The resistance of concrete to acid attack was found by the % loss of weight of specimen and the % loss of compressive strength on immersing concrete cubes in acid water.

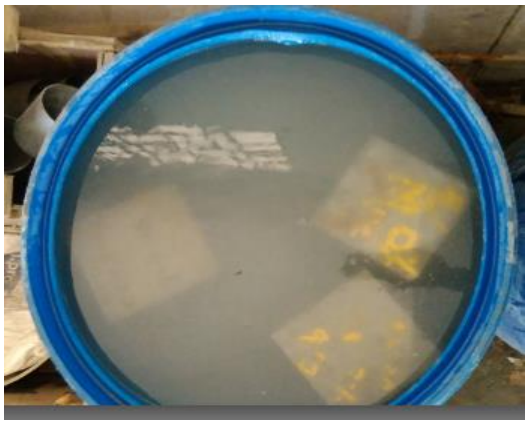
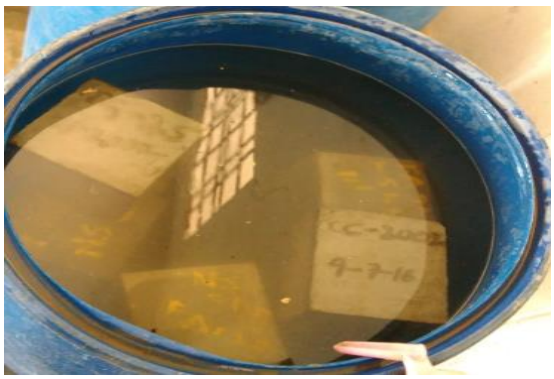


Fig: Durability Test (Acid)

2. DURABILITY BASE TEST:

To determine the resistance of various concrete mixtures to alkaline attack, the residual compressive strength of concrete mixtures of cubes immersed in alkaline water having 5% sodium chloride (Nacl) of by weight of water was found. The concrete cubes which were cured in water for 28 days were removed from the curing tank and allowed to dry for one day. The weights of concrete cube specimen were taken. Then the cubes were immersed in alkaline water continuously for 90 days. The alkalinity of water was maintained same throughout the test period. After 90 days of immersion, the concrete cubes were taken out of alkaline water. Then, the specimens were tested for compressive strength.

The resistance of concrete to alkaline attack was found by the % loss of weight of specimen and the % loss of compressive strength on immersion of concrete cubes in alkaline water.



Fig; Durability Test (Base)

FINAL TEST RESULTS

WORKABILITY

The workability of fresh concrete was found out by conducting slump test as per guidelines of IS: 1199 – 1970. The workability is measured by slump test for fresh concrete

Table: Test results for slump test

S.No	Cement replaced with % of Phosphogypsum	Workability (Slump) ,mm		
		M_{20}	M_{25}	M_{30}
1	0%	76	65	56
2	2.5%	81.32	72.3	63
3	5%	85.45	78.5	68
4	7.5%	83.2	76	65
5	10%	80	73	62

The graph is plotted for workability Vs % of phosphogypsum for M_{20}, M_{25}, and M_{30} grades of concrete as shown in below.

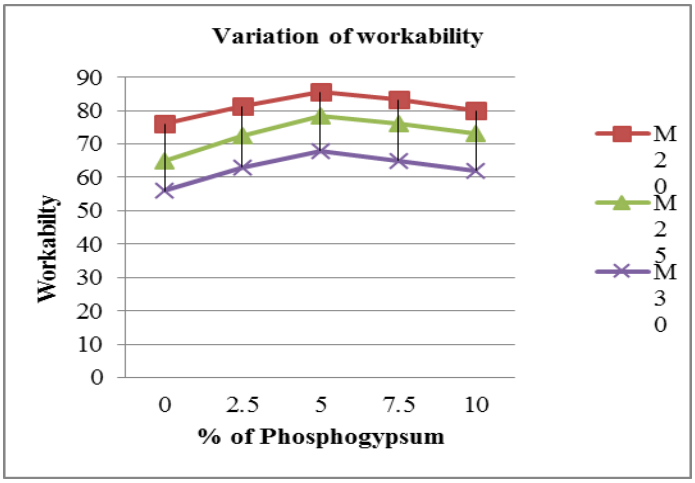


Fig: Variation of workability with % replacement of phosphogypsum.

This indicates that the workability increases up to 5% replacement of phosphogypsum, after that replacement of phosphogypsum, the workability gradually decreases. Thus, the optimum amount of phosphogypsum to be added in the concrete is to be 5%.

DURABILITY ACID TEST

In the compressive strength experimental investigation has been carried for the concrete cubes of M_{20}, M_{25}, M_{30} grades of concrete by percentage 0%, 2.5%, 5% ,7.5 % and 10% of Phosphogypsum as depicted in following tables and graphs.

Table: Compressive Strength test (durability acid).

S.No	Cement replaced with % of Phosphogypsum	Compressive strength (Acid), N/mm^2		
		M_{20}	M_{25}	M_{30}
1	0%	19.85	24.65	29.11
2	2.5%	22.60	28.32	32.40
3	5%	24.32	30.22	33.32
4	7.5%	26.45	31.50	37.45
5	10%	21.54	26.42	33.60

The graph is plotted for Compressive strength (durability acid) Vs percentage of phosphogypsum for M_{20}, M_{25}, and M_{30} grades of concrete as shown in below.

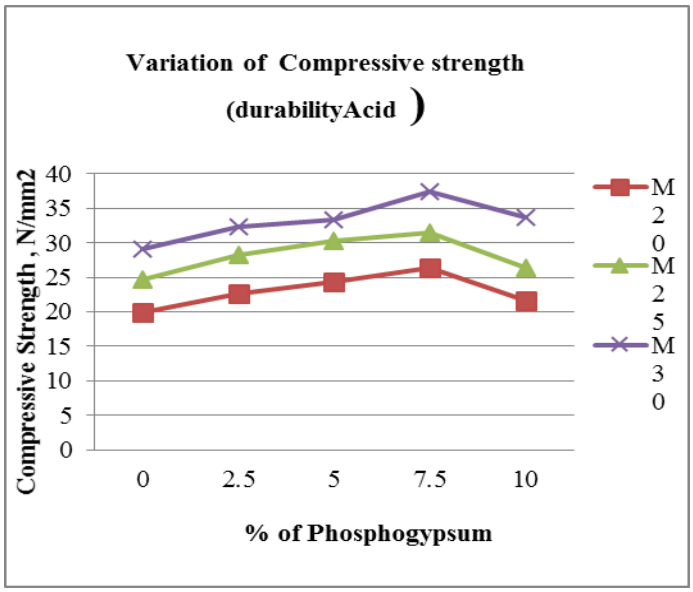


Fig: Variation of Compressive strength (durability acid) with % replacement of phosphogypsum.

This indicates that the compressive strength (durability acid) increases up to 7.5% replacement of phosphogypsum, after that replacement of phosphogypsum, the compressive strength gradually decreases. Thus, optimum amount of phosphogypsum to be added in concrete is found to be 7.5%.

From experimental investigations has been carried for the concrete cubes of weights were taken before kept in curing and after curing with acid. Compare the both results carried the weight loss of hardened concrete specimens as follows below table.

Table: Test results for weight loss (durability acid).

S. No	Cement replaced with % of Phosphogypsum	Weight loss (Acid),kg		
		M_{20}	M_{25}	M_{30}
1	0%	0.08	0.07	0.075
2	2.5%	0.04	0.039	0.045
3	5%	0.045	0.042	0.052
4	7.5%	0.03	0.029	0.044
5	10%	0.07	0.059	0.06

The graph is plotted for weight loss (durability acid) Vs percentage of phosphogypsum weight for M_{20}, M_{25}, and M_{30} grades of concrete as shown in below.

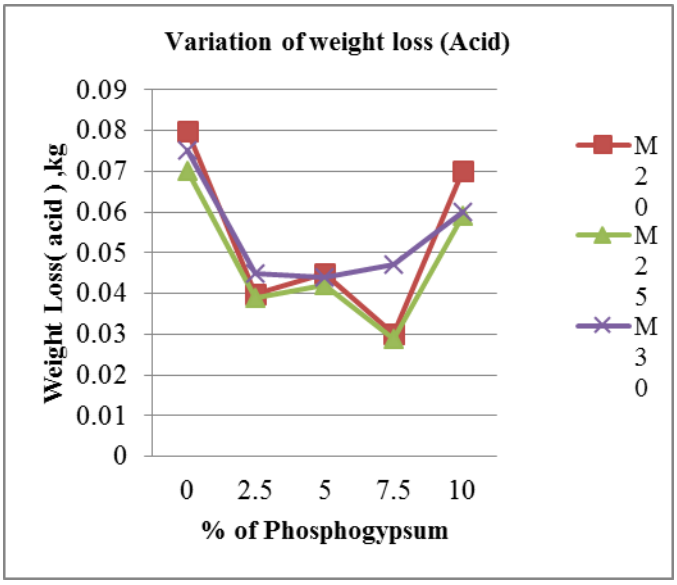


Fig: Variation of weight loss (acid) with % replacement of phosphogypsum.

This indicates that weight losses (acid) decreases up to 7.5% replacement of phosphogypsum, after that replacement of phosphogypsum, weight loss gradually increases. Thus, optimum amount of phosphogypsum to be added in concrete is found to be 7.5%.

DURABILITY BASE TEST

In the compressive strength experimental investigation has been carried for the concrete cubes of M_{20}, M_{25}, and M_{30} grades of concrete by percentages 0%, 2.5%, 5% ,7.5 %and 10% of

phosphogypsum at 28 days as depicted in following tables and graphs.

Table: Compressive Strength test (durability base).

S.No	Cement replaced with % of Phosphogypsum	Compressive strength (Base), N/mm^2 ,		
		M_{20}	M_{25}	M_{30}
1	0%	19.06	25.40	30.42
2	2.5%	20.89	29.00	31.50
3	5%	24.69	30.20	34.62
4	7.5%	27.86	33.02	36.11
5	10%	24.52	25.49	31.40

The graph is plotted for Compressive strength (durability acid) Vs percentage of phosphogypsum for M_{20}, M_{25}, and M_{30} grades of concrete as shown in below.

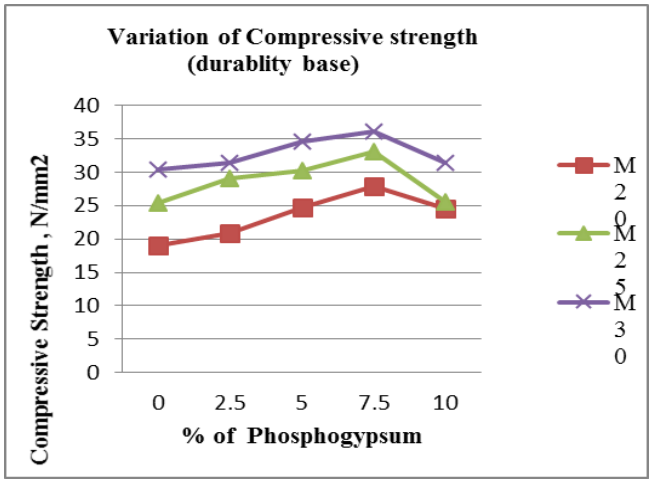


Fig: Variation of Compressive strength (durability base) with % replacement of phosphogypsum.

From experimental investigations has been carried for the cement cubes of weights are taken before kept in curing and after curing with acid. Compare the both results carried the weight loss of hardened concrete specimens as follows below table.

This indicates that the compressive strength (durability acid) increases up to 7.5% replacement of phosphogypsum, after that replacement of phosphogypsum, the compressive strength gradually decreases. Thus, optimum amount of phosphogypsum to be added in concrete is found to be 7.5%.

Table: Test results for weight loss (durability base).

S.No	Cement replaced with % of Phosphogypsum	Weight loss (base) ,kg		
		M_{20}	M_{25}	M_{30}
1	0%	0.17	0.199	0.15
2	2.5%	0.092	0.103	0.10
3	5%	0.099	0.0.98	0.098
4	7.5%	0.09	0.081	0.068
5	10%	0.089	0.098	0.08

The graph is plotted for percentage of phosphogypsum Vs weight loss (durability acid) for M_{20}, M_{25}, and M_{30} grades of concrete as shown in below.

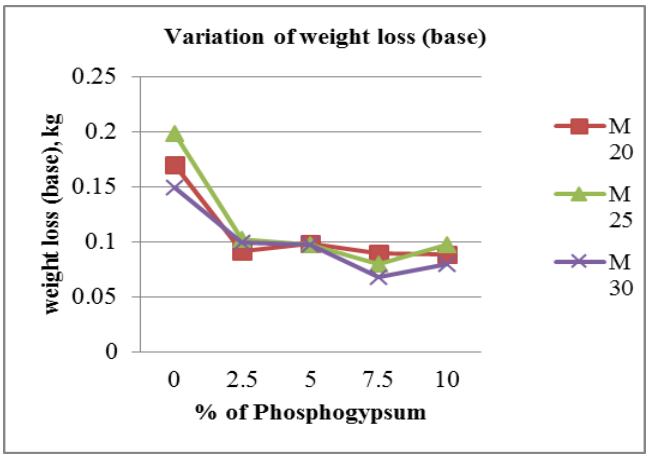


Fig 21: Variation of weight loss (base) with % replacement of phosphogypsum.

This indicates that weight losses (base) decreases up to 7.5% replacement of phosphogypsum, after that replacement of phosphogypsum, weight losses gradually increases. Thus, optimum amount of phosphogypsum to be added in concrete is found to be 7.5%.

CONCLUSION

An industrial waste phosphogypsum impairs the strength development of calcined product and hence it can be used in construction industry for preparation of concrete to achieve the economy. Addition of Phosphogypsum to concrete affects on the durability strength characteristics of concrete. Based on the experimental investigations conclude as follows:

- The workability increases up to 5% replacement of phosphogypsum, after that replacement of phosphogypsum, the workability gradually decreases. Thus, optimum amount of phosphogypsum to be added in concrete is found to be 5%.
- Weight losses (acid) decreases up to 7.5% replacement of phosphogypsum, after that replacement of phosphogypsum, weight loss gradually increases for M_{20}, M_{25} and M_{30} grades of concrete. Thus, optimum amount of phosphogypsum to be added in concrete is found to be 7.5%.
- Weight losses (base) decreases up to 7.5% replacement of phosphogypsum, after that replacement of phosphogypsum, weight losses gradually increases for M_{20}, M_{25} and M_{30} grades of concrete. Thus, optimum amount of phosphogypsum to be added in concrete is found to be 7.5%.
- The compressive strength (durability acid) and the compressive strength (durability base) increases up to 7.5% replacement of phosphogypsum, after that replacement of phosphogypsum, the compressive strength gradually decreases. Thus, optimum amount of phosphogypsum to be added in concrete is found to be 7.5%.

Thus, the phosphogypsum is a byproduct of phosphate fertilizer and chemical industries. It can be effectively utilized by replacement of cement in concrete. Utilization of industrial waste such as phosphogpsum not only solves environmental problems but also provides a new resource for construction industry.

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