A Study on Utilization Aspects of Stone Chips as an Aggregate Replacement in Concrete in Indian Context

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ABSTRACT— ***The high consumption of raw materials by the construction sector, results in chronic shortage of building materials and the associated environmental damage. In the last decade, construction industry has been conducting various researches on the utilization of industrial waste products in concrete in order to reduce the utilization of natural resources.India is pioneer in the exploration, mining of commercial rock deposits and in establishing a firm base for stone industry. Of the 300 varieties of stone; being traded in the world market, nearly half of them are from India.The study concerns mainly on the possible use of stone waste in construction industry, which would reduce both environmental impacts and the production cost. Concrete works in construction industry is particularly important as it is not only responsible for consuming natural resources and energy but also its capacity to absorb other industrial waste. Presently large amounts of stone wastes are generated in natural stone processing plants with an important impact on the environment due to its disposal. Stone chips aggregate are generated as a waste during the process of cutting and polishing of Marble/Granite/Kotastone. This Research Study describes the feasibility of using the Stone Waste chips in concrete production as partial replacement of natural aggregates in Indian context and to reduce disposal and pollution problems. As aggregates are being an important part of concrete by volume and cost. Too, it's necessary to find an effective alternative to reduce the overall cost of concrete without affecting its properties. Stone Chips have such potential as they possess good physical and chemical properties.***

Keywords**—**Stone chips, natural aggregates, concrete, cost

INTRODUCTION

India possesses a wide spectrum of dimensional stones that include granite, marble, kota stone,sandstone, limestone, slate, and quartzite, spread out all over the country. India is also amongst the largest producer of raw stone material and the sector is quite developed and vibrant in the South, as well as in Rajasthan and Gujarat, with a dedicated resource of entrepreneurs.

Stone are the natural, hard substance formed from minerals and earthmaterial which are present in rocks. Rock are the portion of the earth's crusthaving no definite shape and structure. Almost all rocks have a definite chemical compositionand are made up of minerals and organic matter. Some of the rock-forming minerals are quartz,felspar, mica, dolomite, etc. The various types of rocks from which building stones are usuallyderived are granite, basalt, trap, marble, slate, sandstone and limestone.

Stone have still remained a major base in construction industry in India, as there are being used extensively in public buildings, hotels, and temples.

Use of stone in building construction is traditional in the places where it is produced,through its high cost imposes limitations on its use. Stone has been used in the construction of most of the important structures since prehistoricage. Most of the forts world over, the TajMahal of India, the famous pyramids of Egypt and theGreat Wall of China are few examples.

Stone has also been extensively used in almost allthe elements of building structures, as load carrying units as well as for enhancing the beautyand elegance of the structure. As building material stone has gradually lost importance withthe advent of cement and steel. Secondly, the strength of the structural elements built with stones cannot be rationally analysed. Other major factors in overshadowing its use are thedifficulties in its

transportation and dressing which consume a lot of time resulting in slowpace of construction.

AGGREGATES

One of the most particular and general but most important material used for making concrete is AGGREGATE.Aggregates are used as filler with binding materials in production of concrete.Aggregates occupy about 72-75% of volume of concrete and they greatly influence the strength of concrete. These are cheaper than cement and admixtures. The aggregate impart density to concrete. Aggregates may be fine or coarse.The coarse aggregates form the main matrix of concrete and fine aggregate form the filler matrix between coarse aggregates. They may be available naturally or made artificial.

CLASSIFICATION OF AGGREGATES BASED ON SIZE, SHAPE & OTHERS

- Based on unit weight of aggregates
- Based on geological origin
- Based on parent rock
- Based on shape
- Based on size

TABLE 1
CLASSIFICATION OF AGGREGATES BASED ON SIZE, SHAPE & OTHERS

UNIT WEIGHT OF AGGEGATE	GEOLOGICAL ORIGIN	PARENT ROCK	SHAPE	SIZE
•LIGHT WEIGHT AGGREGATE •NORMAL WEIGHT AGGREGATE •HEAVY WEIGHT AGGREGATE	•NATURAL AGGREGATE •ARTIFICIAL AGGREGATE	•IGNEOUS ROCK AGGREGATE •SEDIMENTARY ROCK AGGREGATE •METAMORFIC ROCK AGGREGATE	•ROUNDED •IRREGULAR •ANGULAR •FLAKY •ELONGATED	•FINE AGGREGATE (<4.75mm) •COARSE AGGREAGATE (>4.75)

NATURAL BASALTIC AGGREGATES

Natural basalticaggregate consist of rock fragments that are used in their natural state or used after various mechanical processing such as crushing, sizing, washing etc. Normalweight natural aggregates can be used in all type of work.The specific gravity of these aggregates ranges from 1.5 to2.7. The concrete having density of 2300 kg/m^3 to 2600 kg/m^3 is produced.

CLASSIFICATION NATURAL BASALTICAGGREGATE BASED ON WEIGHT

- Normal Weight Aggregates
- Light Weight Aggregates
- Heavy Weight Aggregates

TABLE 2
CLASSIFICATION OF AGGREGATESBASED ON WEIGHT

CHARACTERISTICS OF AGGREGATES (FACTORS INFLUENCING SELECTION OF AGGREGATES)

1. Strength
2. Stiffness
3. Bond Strength
4. Shape and Texture
5. Specific Gravity
6. Bulk Density
7. Voids
8. Porosity
9. Moisture Content
10. Bulking
11. Fineness Modulus

COMPOSITIONOF NATURAL AGGREGATES

- Some percentage of RCS (Respirable Crystalline Silica)/Free Silica
- Lime (CaO)
- Magnesium oxide (MgO)

PHYSICAL PROPERTIES OF NATURAL AGGREAGATES

Figure 1: Physical Properties of Natural Aggregates

CHEMICAL PROPERTIES OF NATURAL AGGREGATES

Chemical properties of natural aggregatesare varyingand generally depending on source of product.Natural aggregates generally used for construction purpose includes basalt.Basalt is an igneous rock.The aggregate formed from this rock are hard tough and dense.Other rocks like basalt are granite and dolerite.Most often basalt aggregates are used in construction field as aggregates in concrete mix. Moreover basalt is hard and dense rock,normally undergoes very little creep or no creep.The modulus of elasticity of naturally occurring hard aggregates is one of the important factors influencing creep. Out of all natural aggregate basalt is more preferred.

BASALT AS CONSTRUCTION MATERIAL

The main properties of Basalt are as follows:

- Basalt is a dense looking black volcanic rock.
- Its texture is fine grained to glassy.
- It is composed of Plagioclase, Hornblende, Olivine, Biotite and Iron Oxide.
- It has been estimated that Basalt is $5/6^{th}$ of all the volcanic igneous rocks of the world.
- Basalt sometimes contains residues which have become filled with secondary minerals like Quartz, Calcite and Zeolite.

USES OF BASALT

- The crushed Basalt is used as road metal and concrete aggregate.
- Basalt is an important rock used in the construction of bridges, pavements of highways, railways and other engineering works.
- It is not used for very important buildings because of its dark colour and the quality of not taking good polish.

INTRODUCTION TO STONE CHIPSAGGREGATES

The aggregates formed from basalt rock are used for construction work due to high strength and hardness.In recent times there has been a shortage of construction material and hence artificial replacement of construction materials is made possible fully or partially.This idea also keeps the concept of attaining nearly same or same strength as obtained by the basic construction materials. Keeping in mind the economic feasibility and technical viability of thehandled project, the work admires the replacement of natural aggregates by stone chips (waste or scrap of quarry). This will lead to effective utilisation of such waste in worthy works of construction.Tons and tons of such kind a waste is generated every year from quarries, which is rendered useless and may also spoil the aesthetics of surrounding regions.

CHEMICAL COMPOSITION OF MARBLE,GRANITE AND KOTASTONE

TABLE–3
CHEMICAL COMPOSITION OF MARBLE, GRANITE,KOTASTONE

Chemical Composition	Marble	Granite	Kota Stone
Lime	28-32%	1-4%	37-39%
Silica	3-30%	72-75%	24-26%
MgO	20-25%	05-1%	4-6%
$FeO+Fe_2O_3$	1-3%	-	-
Loss of ignition	20-45%	5-10%	32-35%

Source:Mamta B. Rajgor,Jayeshkumar Pitroda (A study of utilization of stone waste in Indian context)

It is found that stream materials,crushed stones and artificial aggregates have been used in concrete aggregate in the world.It is unquestionable and more suitable material than other aggregate types. Same units can make stone grit and chips, butcurrentlychips are more in demand. The demand for stone chips is directly linked with the volumeof construction activity. Stone chips are used in concreting, along with cement and sand and inroad pavement work. Looking at the decreasing economic costs involved with storage while preventing possible environmental negative impacts it can be considered as a future pre-requisite to use crushed stone chips for construction in countries having scarce resource.

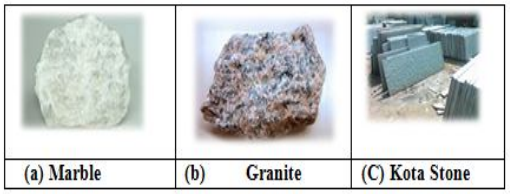

Figure2: Stones: Marble, Granite, Kota Stone
Source: www.geology.com

RAW MATERIALS USED FOR STONE CHIPS:

It can be collected from the stone quarry. It is available as waste product of quarry. From such waste stone chips can be produced.

TABLE–4
QUARRY WASTE CLASSIFICATION

Group	Description	Example	Potential End Uses
Type 1	Unprocessed waste: large volume, low value industrial minerals; commonly used in construction applications; market would be located in close proximity	quarry scalpings; quarry blocks; colliery spoil	Fill, low grade road stone, armour stone, brick clay
Type 2	Processed waste – reclaimed minerals: only a small amount of processing is required; market largely local; a small amount of secondary waste will be produced	silica sand waste; limestone waste; building stone waste	Silica sand, kaolin, brick clay, mineral filler, aglime, aggregate
Type 3	Processed waste – added-value products: contain small amounts of valuable minerals; potentially complex processing is required; major capital investment; large volumes of secondary waste	Lead/zinc waste; pegmatite waste; silica sand waste	Fluorite, barite, feldspar, rare earths, mica, heavy minerals
Type 4	Beneficiated wastes: contain small quantities of highly valuable minerals; complex processing requirements; large volumes of secondary waste; international market	Specific mine wastes	Gemstones, other high value metals

Source:Evaggelia Petavratzi, Scott Wilson(Sustainable utilisation of quarry by_products)

TABLE–5
APPLICATION OF MARBLE QUARRY WASTE

APPLICATION	MABLE QUARRY WASTE
Bituminous wearing course	+
Bituminous layers, except wearing courses	+
Unbound road base	++
Unbound sub base	+++
+++ :complies with almost all requirements	
++ :could comply with all requirements, if some minor treatments are done	
+ :does not comply with requirements, even if treatments are done	

Source: Helena Lima;ICOR-Road construction institute,Portugal(Applicability of marble quarry waste in pavement layers)

CASE STUDY

Dushyant R. Bhimani, Prof. Jayeshkumar Pitroda, Prof. Jaydev J. Bhavsar (2013), "Innovative Ideas for Manufacturing of the Green Concrete by Utilizing the Used Foundry Sand and Pozzocrete" International Journal of Emerging Science and Engineering TM, IJESE

In thepresentstudy, effect of stone chips aggregateas coarseaggregate replacementonthecost of concrete having mix proportions of 1:1.48:3.21 was designed as per IS: 10262:2009 methods was investigated. Thepercentages of replacementswere 0%, 10 %,20%, 30%, 40% and 50%byweightof coarseaggregate.The design mix proportion is done in Table 6. And economical feasibility is done in table-7&8.

TABLE - 6
M20 MIX DESIGN PROPORTIONS

Natural basaltic aggregate replacement by stone chips aggregate						
By weight, [kg]	0%	10%	20%	30%	40%	50%
W(Lit)	191.60	191.60	191.60	191.60	191.60	191.60
C(Kg/m^3)	383.21	383.21	383.21	383.21	383.21	383.21
F.A.(Kg/m^3)	569.38	569.38	569.38	569.38	569.38	569.38
C.A.(Kg/m^3)	1231.11	1108.00	984.89	861.78	738.67	615.55
S.C.A.(Kg/m^3)	-	123.11	246.22	369.33	492.44	615.55

W= Water, C= cement, F.A. = Fine Aggregate, C.A. = Coarse Aggregate, S.C.A. = Stone Chips Aggregate

TABLE- 7
COSTS OF MATERIALS

Sr. No.	Materials	Rate (Rs/Kg)
1	Cement (OPC 53 grade)	6.00
2	Fine aggregate (Regional)	0.61
3	Coarse aggregate (Regional)	0.65
4	Stone chips aggregate	0.20

TABLE - 8
TOTAL COST OF MATERIALS FOR M20 DESIGNE MIX CONCRETE (1:1.48:3.21) PER m^3

C.T.	Consumption of Design Mix Proportions For M20 Concrete (1:1.48:3.21)				Total Cost /m^3	% Cost change
	C	F.A.	C.A.	S.C.A.		
A0	383.21	569.38	1231.11	-	3446.80	0
A1	383.21	569.38	1108.00	123.11	3391.40	-1.61
A2	383.21	569.38	984.89	246.22	3336.00	-3.21
A3	383.21	569.38	861.78	369.33	3280.60	-4.82
A4	383.21	569.38	738.67	492.44	3225.20	-6.43
A5	383.21	569.38	615.55	615.55	3169.79	-8.04

C.T. = Concrete Types,C= Cement, F.A. = Fine Aggregate, C.A. = Coarse Aggregate, S.C.A. = Stone Chips Aggregate

CONCLUSION

a) We can say that for 1m3 M20 grade of concrete consumption of coarse aggregate is 1231.11kg. Here in specimen A1, A2, A3, A4, A5 we replace coarse aggregate by 10 %,20%, 30%, 40% and 50% by weightof coarse aggregate for 1m^3 M20 grades of concrete.

So, as per literature review conclude that up to approximate 30% stone chips aggregate utilized for economical and sustainable development of concrete.

b) If compressive strength is not achieved as per design the use of admixture recommended achieving in strength. So stone chips aggregate in concrete can save the stone industry disposal costs and produce a 'greener' concrete for construction.

c) Stone chips are providing a cost effective alternative to conventional natural aggregates, by reducing the cost of concrete.

d) It reduces the depletion of conventional coarse aggregates from environment and also enables to produce Green Concrete.

e) Thus, an innovative supplementary Construction Material is formed through this study.

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