Converting Plastic **into Construction Bricks.**

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Key Insights/ Abstract

Pakistan's construction industry mainly uses earth fired bricks, whose production leads to emissions of CO2, CO, SO2, other noxious pollutants and the loss of precious top soil. Plastic waste is a major pollutant globally and recycling plastic (PET) into bricks for construction would reduce waste and encourage a new cottage industry becoming a catalyst of social change, impacting those suffering as bonded labour in the brick kiln industry.

Of the five samples initially envisaged, two variants of the bricks were made, one in tile form (9"x4.5"x2") and the other in brick form (9"x4.5"x3"). Both variants were sent for stress testing at UET Civil Engineering Lab, Lahore. The results were extremely positive as the tile and brick models were able to build approximately 473ft and 150ft tall buildings respectively (considering a safety factor of 10) without any additional mechanical support.

A survey conducted of randomly selected civil engineers about viability of the usage of bricks in construction showed that there was keen interest in using the bricks in commercial and residential structures.

The production process involved batching and heating PET to 450°C, mixing it into a set ratio of fine grain river sand and cooling the resultant mixture in a metallic mould. The weight and stress characteristics depend on the ratio of sand and plastic. Two variants, using ratios 1:1 and 2:3, were made and the characteristics compared to the standard earthen brick. The results were positive and proved that plastic bricks can be used for construction purposes.

The environmental and social impact of this initiative would benefit from government support and policy changes like taxing the traditional brick kilns for net environmental impact. The use of plastic bricks for outer walls and pavements etc, should be encouraged until research and testing clears it for final use in habitable structures.

Research Context

Currently, the construction industry uses bricks that are made in brick kilns using top soil from the agricultural areas surrounding major cities. There are around 15,000 Fixed Chimney Bulls Trench Kilns (FCBTK) in Pakistan. Most of the brick kilns are coal fired or burn plastic without any emission controls and thereby produce NO2, SO2, CO and CO2 along with particulate matter polluting the air. (Secretariat)

Traditionally, most of the brick kilns use bonded labour, a grave human rights travesty giving rise to severe and continued poverty. The main raw material used to make earth bricks is top soil. Precious top soil is lost to making bricks causing loss of fertile land that could otherwise be used for agriculture and negatively effect viable produce for our growing population. Making an impact to the brick kiln industry can, thus, cause lead to fringe and direct benefits in terms of society and the environment. Currently the industry is unregulated and the current environmental and labour laws are not fully enforced. (Climate and Clean Air Coalition)

A major cause of environmental pollution is plastic waste. Rising numbers of FMCG companies in the market means more and more plastic waste is being produced and dumped into the environment. Unless this plastic waste is reused, it will be impossible to control the impact as studies show that it can take up to 450 years for PET

Bottles to decompose. (Gammage) (Ioakeimidis et al.)

The purpose of this research was to recycle the plastic of PET bottles and convert them into usable construction bricks, thereby solving two problems - one of waste plastic in the environment and two, reducing the noxious emissions of the present FCBTK based earthen bricks. (Suriyaa et al.) describe the technical attributes of the plastic bricks including size, compression strength and Maximum Load that are required to make the brick useful. However, the document does not cover details of the energy efficient production Process and adoption challenges for local workforce and the preferences of construction industry.

The production method was designed to be simple so the local labourers currently involved in the brick kiln industry can easily transfer his/her skills to this new industry. Most of the commercial grade research on fabrication methods involve methods mentioned in (Chauhan).

The method mentioned, however, requires very little capital investment; however, the method has been further streamlined in order to lower the barrier to entry for the small investor. The four step production process mentioned in the paper comprises of

- Batching
- Burning
- Mixing
- Moulding

Two of the four processes (burning and mixing) require energy and heat. This increases the energy consumption, resulting in increased cost of production and negative environmental impact. One of the goals of this research was to make the production process energy efficient while reducing emissions by reducing the number of steps in the process.

It was important to ensure that the plastic bricks are useable based on their ultimate compressive strength so that they are viable to use as a construction material. It was also important to learn about the likelihood of adoption of this new material by the influencers of the construction industry e.g. civil engineers.

A survey of engineers was conducted along with third party verification of the technical and physical attributes of the two variants of the bricks produced in order to understand the adoption challenges and the usability of the plastic brick. The bricks produced by the new production method were then benchmarked by the bricks produced by FBTCK bricks for ultimate stress and load in order to gauge the actual utilization of bricks.

It is also essential to improve the policies regulating the brick kiln industry that is currently not regulated. The environmental laws and the labour laws need to be enforced. In addition, taxes need to be imposed on the brick kiln industry in order to support their movement to the plastic brick manufacturing. The public sector procurement rules (PPRA) also need to be modified to encourage the use of plastic bricks by the engineering firms for government projects. (Dubey)

Research Design

Initially four variants were tested with the following consistency:

Variant	Description
1	By Weight Sand Plastic 1:1
2	By Volume Sand/Plastic 1:1
3	By Weight Sand to Plastic 2:3
4	By Volume Sand to Plastic 2:3

Variant 2 and Variant 3 were chosen as the rest were too brittle to survive the manufacturing process. Variant 2 was moulded in tile form and Variant 3 in brick form.

Figure 1: Variant 2

Figure 2: Variant 3

The manufacturing process comprised of three stages

1. Batching
2. Mixing
3. Moulding

In the batching process, cut and weighed PET bottles were used with small grain Ravi sand. At 300°C, reweighted sand was added and thoroughly mixed. The mixture was then heated for 15 minutes at 450°C and slowly cooled to room temperature.

Four samples of each of the variants were created and sent to Plain and Reinforced Concrete Laboratory, Civil Engineering Department at University of Engineering and Technology, Lahore for Load and Stress Testing. (Attached as Appendix A)

The ultimate load data of the two variants was analysed with safety factor 10 and the height of the building, without engineering and mechanical support, was computed to ensure that the bricks could sustain the weight of the construction. The computations are shown in the key findings section of this document for each of the variants.

NOx and SOx testing could not be done during the allocated time as laboratories were closed during Ramzan and Eid holidays. However, it is not expected that the bricks would have any harmful chemicals as they are made from, generally, food grade plastic materials.

The bricks, once made, were again heated to determine if and when any deformities occurred. This helped conclude the range of uses of the

bricks and the temperature ranges where they worked well, considering Pakistan's variety of weather patterns.

The second part of the research included utilization survey results from civil engineers which concluded that consistency of size and quality were problems with earth fired bricks. There was overwhelming support for the use of plastic bricks. Appendix C contains survey questionnaire and responses.

Key Findings and Discussion

Pollution Problem
Pollution because of excessive production and mismanagement of plastic waste remains a major problem for our society. The problems is accentuated by the brick kiln industry which causes so much air pollution that it makes air unhealthy to breathe in most parts of Pakistan. Both problems can be simultaneously resolved by converting plastic to bricks.

1) Plastic Pollution
According to (Khan) 70% of around 2.6 million tons of plastic is mismanaged and left to the landfills or unmanaged dumps. With the annual production of about 3.9 million tonnes of waste, unless it is recycled at an industrial scale, we have serious problem on our hand.

2) Environmental Pollution of Brick Industry
According to (Secretariat) The 20,000 brick kilns in Pakistan are one of the major causes of pollution. Globally brick kilns account for 20% of the black carbon emissions. (Kanabkaew and Buasing), shows that emissions for each brick kiln including PM10, CO and SO2 were ranged between 0.0346–0.0751, 1.3022–3.3603 and 0.1736–0.4481g/s, respectively. This problem is quite acute and needs to be handled immediately.

Plastic waste to Construction Bricks

In order to convert plastic into construction quality bricks the choice of raw materials and the production process has to be followed as described below.

1) Raw Materials Usage

The raw materials used for this research are as follows:

a. Plastic
There are several types of plastics, however, for the purpose of bricks Polyethylene Terephthalate (PET) -(C10H804)n – was used. PET is non toxic, extremely hard and has a melting point of 260°C. (Staff)

PET is used make plastic bottles for beverages and is considered harder than most other forms of plastics. A number of FMCG companies now distribute their products in PET bottles making it readily available in the market. The PET bottles were washed, cut into small pieces and weighed into 1kg blocks.

b. Sand
Fine grain sand was used as it mixes easily and can help increase the tensile strength of PET without impacting the chemical bond of the polymer. River sand from River Ravi was used for mixing after being put through a 9mm sieve.

2) Production Process

The final production process was divided into three stages

a) Batching

At the batching stage of production, PET bottles were cut into smaller, approximately 2in x 2in or even smaller pieces. The cut pieces were weighed and 1kg of plastic was taken in a batch. River sand of 0.5kg batches were sieved using 9mm sieve and then stored.

b) Mixing

The plastic PET was heated in a cauldron. At 200°C, small amounts of sand was added and more and more PET and sand was added to maintain the ratio of Plastic vs Sand (1:1) or (2:3) depending on which variant was to be produced. Once the ratios are maintained and sand is completely absorbed by the mixture, it is heated up to 450°C while constantly stirring the mixture so that sand is evenly distributed in the entire solution. The burning and the mixing steps as mentioned in (Chauhan) were merged into one step in order to conserve energy. The two step process is longer and requires more energy.

c) Moulding

The solution is then slowly poured into a precast metallic mould the size of the variant being produced and allowed to cool naturally.

3) Final Product Analysis:

Two different variants were created and tested at UET Civil Engineering Lab for analysis and the report is attached (Appendix A).

	Size (inch)	Dry Weight (gms)	Ultimate load (Imp. Tons)	Ultimate Stress (PSI)
Variant 2 (2:3)	8.9x4.4x1.9	1640	49	2803
Variant 3 (1:1)	8.8x4.3x3	2975	18	1056

The final manufactured brick was similar in size and dimensions as corroborated by the Lab results in Appendix A. The final product was within 10% margin and improved manufacturing systems can make the final finished product more consistent.

For Variant 2, the lab results show that the ultimate load was 49 tons (49000kg) and the Ultimate Stress was 2803PSI. Through computations it is easy to conclude that, with Variant 2 and a safety factor of 10, one can have a 493ft high structure putting these bricks end to end as compared to the standard brick with the compressive strength of about 1500PSI. We can see from (Guide et al) that the variant one falls into Brick Class of 175 and can be used in construction. The weight of this variant is 1640mg which is much less than the 3.1kg ("What Is the Weight of a Standard Brick and Their Size") research can be used in construction.

Variant 3 was built using 2:3 ratio by weight between sand and plastic. With a safety factor of 10, the ultimate load factor of 18 Imperial Tons, translates into a height of 150ft where the bricks can be put end to end without any additional support. The Ultimate Stress of 1056PSI, firmly puts the brick into Brick Class designation of 75 which can be used for construction. The lower weight of the plastic brick 2.9kg compared to 3.1kg makes it easier to transport..

Utilization Survey

The survey (Appendix B) was conducted with civil engineers from Lahore. Over 300 surveys were

floated and 21 responses were received. The poor response can be attributed to Ramzan and Eid holidays when the survey was conducted. 100% of the respondents mentioned consistency of size, compressive strength among the top five factors impacting the adoption of plastic bricks. 93% of the respondents mentioned size and consistency as major issues with the current brick. 98% of the respondents were open to the use of Plastic bricks provided production process is certified by government bodies.

CONCLUSION

We can conclude from our research that that PET bottles can be safely used wherever construction bricks in Pakistan are used. In addition to the obvious advantages of controlling pollution (both air and land), the bricks have a few more advantages:

- Simple and easy labour training required for production
- Low fixed cost for production facility so lower barrier to entry
- Lower transport cost because of light weight

Policy Recommendations

In order to encourage the conversion of existing brick making industry to plastic based bricks the government at Provincial and Federal levels as well as donor agencies have to make a few policies.

1. Protect Top Soil by imposing sales tax per meter on the size of lot used by brick kilns where top soil is excavated.
2. Impose Sales Tax for brick kilns on the production capacity. This will tax every brick being manufactured and pay for the impact on air pollution.
3. Donor agencies and Govt should ensure that all new projects that require construction use plastic bricks.
4. Government gives 10 points extra on tender evaluation if the bidder uses plastic bricks instead of earthen bricks.
5. An additional 3% tax is imposed on the builder if they use earth bricks instead of plastic bricks.
6. All commercial and residential housing colonies give extra tax if they do not separate plastic waste from other waste.
7. HEC should provide grants to educational institutes for research on refining the idea of plastic bricks for extensive usage.
8. SMEDA and TEVTA needs to promulgate policies to train the workforce on making plastic bricks and encourage research on improving the quality.
9. Only kilns licenced and certified by EPA, under the guidance of Ministry of Environment, should be allowed to operate provided they satisfy all environmental regulations.

References

1. C H, Sheshachala, et al. "UTILIZATION of WASTE PLASTIC in MANUFACTURING of BRICKS." International Journal of Scientific & Engineering Research, vol. VOL 10, no. Issue 4, Apr. 2019. ISSN 2229-5518, www.citefactor.org/journal/pdf/UTILIZATION-OF- WASTE-PLASTIC-IN-MANUFACTURING-OF-BRICKS.pdf.

2. Chauhan, S S. "Fabrication and Testing of Plastic Sand Bricks." Https://Iopscience.iop.org/, 2019,iopscience.iop.org/article/10.1088/1757-899X/691/1/012083/pdf.

3. Gammage, Emmanuelle. "How Long Does It Take for Plastic to Biodegrade?" SaveMoneyCutCarbon, 17 Feb. 2021, www.savemoneycutcarbon.com/learn-save/how-long-does-it-take-for-plastic-to-biodegrade/#:~:text=Both%20processes%20are%20dependent%20on.

4. Ghani, Faras. "The Spiralling Debt Trapping Pakistan's Brick Kiln Workers." Www.aljazeera.com, 21 Oct. 2019, www.aljazeera.com/features/2019/10/21/the-spiralling-debt-trapping-pakistans-brick-kiln-workers.

5. Guide, Posted in How To, et al. "Compressive Strength Test on Bricks." The Constructor, 12 Dec. 2013, theconstructor.org/practical-guide/compressive-strength-test-on-brick/2790/.

6. Ioakeimidis, C., et al. "The Degradation Potential of PET Bottles in the Marine Environment: An ATR-FTIR Based Approach."Scientific Reports, vol. 6, no. 1, 22 Mar. 2016, 10.1038/srep23501. Accessed 5 Dec. 2019.

7. Kanabkaew, T., and K. Buasing. "Assessment of Air Pollution Concentrations from Brick Kilns Using an Atmospheric Dispersion Model." Witpress.com, 2015, , www.witpress.com/elibrary/wit-transactions-on-ecology-and-the-environment/198/33792.

8. Khan, Malik Amin Aslam. "4 Ways Pakistan Is Tackling Plastic Waste and Pollution." World Economic Forum, 21 Nov. 2021,www.weforum.org/agenda/2021/11/4-ways-pakistan-is-tackling-plastic-waste-and-pollution/.

9. Secretariat, CCAC. "Pakistan Moves toward Environmentally Friendly and Cost-Effective Brick Kilns." Climate & Clean Air Coalition, 10 Apr. 2018, www.ccacoalition.org/en/news/pakistan-moves-toward-environmentally-friendly-and-cost-effective-brick-kilns.

10. Staff, Creative Mechanisms. "Everything You Need to Know about the World's Most Useful Plastic (PET and Polyester)." Https://Www.creativemechanisms.com/Blog/Everything-About-Polyethylene-Terephthalate-Pet-Polyester, 20 June 2016, www.creativemechanisms.com/blog/everything-about-polyethylene-terephthalate-pet-polyester.

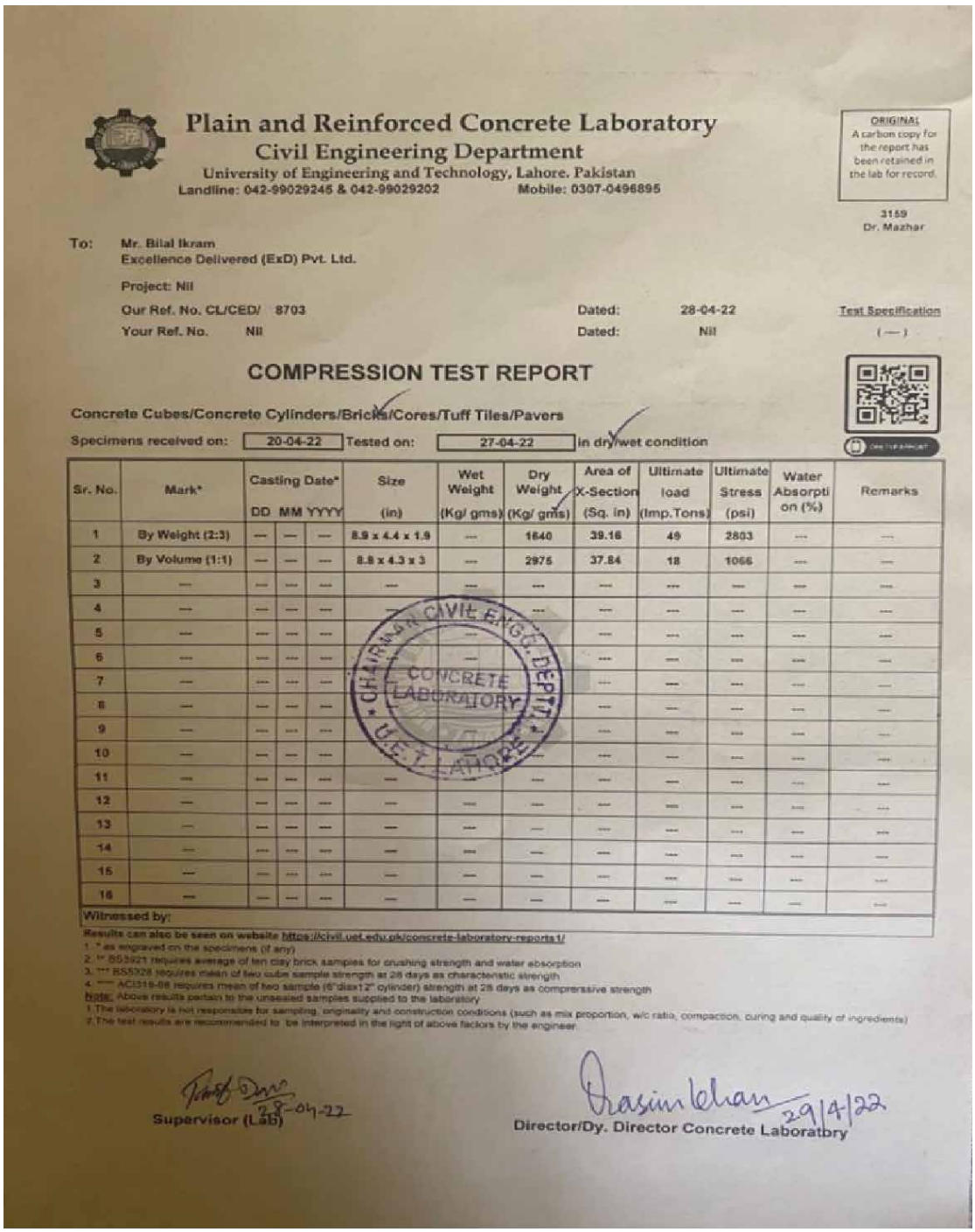
11. Suriyaa, M, et al. "Experimental Study on Strength Behaviour of Plastic Sand Bricks." International Journal of Scientific Engineering and Research (IJSER), vol. 9, no. 6, 6 June 2021, www.ijser.in/archives/v9i6/SE21524114751.pdf, 10.21275/SE21524114751.

12. "What Is the Weight of a Standard Brick and Their Size." Civil Sir, 7 Apr. 2021, civilsir.com/weight-of-a-brick/.

13. "Fact Sheet Brick Sector Pakistan.pdf." Climate & Clean Air Coalition, www.ccacoalition.org/en/files/fact-sheet-brick-sector-pakistanpdf. Accessed 8 May 2022.

14. Dubey, R M. GUIDELINES on BRICK MANUFACTURING UNIT INTRODUCTION. 20 Dec. 2012.

Appendix A: Compression Test Report



Plain and Reinforced Concrete Laboratory
Civil Engineering Department
University of Engineering and Technology, Lahore. Pakistan
Landline: 042-99029245 & 042-99029202 Mobile: 0307-0496895

ORIGINAL
A carbon copy for the report has been retained in the lab for record.

3159
Dr. Mazhar

To: Mr. Bilal Ikram
Excellence Delivered (ExD) Pvt. Ltd.

Project: Nil

Our Ref. No. CL/CED/ 8703 Dated: 28-04-22 Test Specification

Your Ref. No. Nil Dated: Nil (—)

COMPRESSION TEST REPORT

Concrete Cubes/Concrete Cylinders/Bricks/Cores/Tuff Tiles/Pavers

Specimens received on: 20-04-22 Tested on: 27-04-22 in dry/wet condition

Sr. No.	Mark*	Casting Date* DD	MM	YYYY	Size (in)	Wet Weight (Kg/ gms)	Dry Weight (Kg/ gms)	Area of X-Section (Sq. in)	Ultimate load (Imp.Tons)	Ultimate Stress (psi)	Water Absorption (%)	Remarks
1	By Weight (2:3)	—	—	—	8.9 x 4.4 x 1.9	—	1640	39.16	49	2803	—	—
2	By Volume (1:1)	—	—	—	8.8 x 4.3 x 3	—	2975	37.84	18	1066	—	—
3	—	—	—	—	—	—	—	—	—	—	—	—
4	—	—	—	—	—	—	—	—	—	—	—	—
5	—	—	—	—	—	—	—	—	—	—	—	—
6	—	—	—	—	—	—	—	—	—	—	—	—
7	—	—	—	—	—	—	—	—	—	—	—	—
8	—	—	—	—	—	—	—	—	—	—	—	—
9	—	—	—	—	—	—	—	—	—	—	—	—
10	—	—	—	—	—	—	—	—	—	—	—	—
11	—	—	—	—	—	—	—	—	—	—	—	—
12	—	—	—	—	—	—	—	—	—	—	—	—
13	—	—	—	—	—	—	—	—	—	—	—	—
14	—	—	—	—	—	—	—	—	—	—	—	—
15	—	—	—	—	—	—	—	—	—	—	—	—
16	—	—	—	—	—	—	—	—	—	—	—	—

Witnessed by:

Results can also be seen on website https://civil.uet.edu.pk/concrete-laboratory-reports1/

1. * as engraved on the specimens (if any)
2. ** BS3921 requires average of ten clay brick samples for crushing strength and water absorption
3. *** BS8328 requires mean of two cube sample strength at 28 days as characteristic strength
4. **** ACI318-08 requires mean of two sample (6"diax12" cylinder) strength at 28 days as compressive strength

Note: Above results pertain to the unsealed samples supplied to the laboratory

1. The laboratory is not responsible for sampling, originality and construction conditions (such as mix proportion, w/c ratio, compaction, curing and quality of ingredients)
2. The test results are recommended to be interpreted in the light of above factors by the engineer

CHAIRMAN CIVIL ENGG. DEPTT. U.E.T. LAHORE CONCRETE LABORATORY

Supervisor (Lab) 28-04-22

Director/Dy. Director Concrete Laboratory 29/4/22

Appendix B: Survey Responses:

Participant Consent Form

RESEARCH Converting Plastic into Construction Brick

In signing this consent form, I confirm that:	Yes	No
I have read the Project Information Sheet and the nature and purpose of the research project has been explained to me.		
I have had the opportunity to ask questions.		
I understand the purpose of the research project and my involvement in it.		
I understand that my participation is voluntary, and I may withdraw from the research project at any stage, without having to give any reason and withdrawing will not penalise or disadvantage me in any way.		
I understand that while information gained during the study may be published, any information I provide is confidential (with one exception – see below), and that no information that could lead to the identification of any individual will be disclosed in any reports on the project, or to any other party. No identifiable personal data will be published.		
I understand that the researcher may be required to report to the authorities any significant harm to a child/young person (up to the age of 18 years) that he/she becomes aware of during the research. I agree that such harm may violate the principle of confidentiality.		
I agree that extracts from the interview may be anonymously quoted in any report or publication arising from the research.		
I understand that the interview will be recorded using audiotape/electronic voice recorder/video recorder.		
I understand that data will be securely stored.		
I understand that I may contact the researcher (Ismail Mustafa Syed) if I require further information about the research, and that I may contact the Safeguarding Focal Point at UNDP **Fatima Ahmed,** if I wish to make a complaint relating to my involvement in the research.		
I agree to take part in the above research project.		

Participant's name (BLOCK CAPITALS)	Participant's signature	Date
Researcher's name (BLOCK CAPITALS) {Do not need to fill}	Researcher's signature{Do not need to fill}	Date {Do not need to fill}

Note: The Name / Identity of Participant will be kept confidential and not published.

Draft Questionnaire for Civil Engineers (Design and / or Construction Industry)

The filled-in questionnaire may please be sent returned to ismailsyed2005@gmail.com or by WhatsApp to

+923458477393

1	What is the size of buildings you design and /or construct every year?	
2	How many buildings do you build and/or design?	
3	What would be the typical number of traditional bricks* you use yearly? OR What would be the typical number of traditional bricks specified in your design yearly?	
4	On average, how many traditional bricks do you use in the building (indoors and outdoors)? OR On average, how many traditional bricks are used in your design of buildings (indoors and outdoors)?	Indoors: Outdoors:
5	What characteristics are you looking for in construction bricks?	1. 2. 3. 4. 5.
6	Are you facing problems with traditional bricks? Yes / No	Yes / No If No, please provide some reasons.
7	Would you be interested in using Plastic Bricks** in your construction/design Yes / No?	Yes / No If No, please provide some reasons.
8	What is the average price of traditional bricks you use in your design and/or construction of buildings?	

9	Are EHS factors important in the selection and use of bricks in your design and/or construction Yes/No?	Yes / No If Yes, what EHS factors are important in choosing a material.
10	What specifications would you be looking for in a plastic brick? OR What characteristics would be important in the usability of a plastic brick for you?	1. 2. 3. 4. 5.
11	What materials do you specify for joining and plastering traditional bricks in your designs? OR What other construction materials do you use for joining and plastering of traditional bricks?	1. 2. 3. 4. 5.

Notes:

* Normal clay bricks used regularly for construction projects in Pakistan

** Plastic-River sand hybrid brick; Size 9 ins x 4.5 ins x 4ins, made by employing PVC/PET / recycled PVC.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